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THE INFLUENCE OF AIRCRAFT NOISE ANNOYANCE ON SINGLE-FAMILY HOUSE PRICES: A CASE STUDY OF EDMONTON'S INDUSTRIAL AIRPORT

by

© HANS-WERNER MARY

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The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research, for acceptance, a thesis entitled "The Influence of Aircraft Noise Annoyance on Single-Family House Prices: A Case Study of Edmonton's Industrial Airport" submitted by Hans-Werner Mary in partial fulfilment of the requirements for the degree of Master of Arts.

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ABSTRACT

An ever-increasing number of aircraft noise damage suits suggests that people fear for the devaluation of their properties. One of the main hindrances to successful litigation, however, is the difficulty of proving that noise has indeed caused a devaluation of single-family houses. The available literature is contradictory, though tending to favour the view that residential property values are not depreciated by aircraft noise.

In a case study of the impact of the municipal airport in Edmonton, a new method is shown by which, with reasonable accuracy, the degree of noise annoyance can be calculated retroactively. Furthermore, the study area's socio-economic, locational and physical properties are traced back to the time from when sales data were collected, thus allowing a precise selection of noise-affected homes and their noise-free control counterparts.

It was found that houses under the influence of aircraft noise appreciated in price faster than the quiet homes, even to the extent of a direct relationship: the noisier the house, the steeper the price slope (i.e. the greater the price increase). This result is supported to some degree by two questionnaires whose findings show that almost one-half of the people contacted do not mind the noise, and that used homes under a noise or flight path can easily be financed through conventional money sources.

In conclusion, it is demonstrated that there is a need for a revised noise annoyance measurement system that will account for the presently neglected small airplanes, and which can incorporate meteorological data.

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CHAPTER ONE

INTRODUCTION

I live not by myself, but I become a
Portion of that around me: and to me
High mountains are a feeling,
But the hum
Of human cities tortures.

One can dispute whether Lord Byron foresaw either the structure or the traffic of cities as we know them today. But there are a great many people who now share his view that city noise is fairly described as torture. One of its main components, aircraft noise, in particular that of jet planes, is loud by any standard. Although medical research on the effects of noise is incomplete, there is increasing evidence that prolonged exposure to aircraft noise has serious adverse effects (Haar, 1968, p.551).

The problem is best understood through a comparison: the acoustic power produced by one person speaking in a normal voice is about .000001 watt. The corresponding value of London's inhabitants speaking simultaneously would be about 100 watts, equal to the energy used by a 100-watt light bulb. But the total acoustic power radiated into the air by a passenger jet during take-off is several hundred kilowatts. No wonder that noise from aircraft operations is a nuisance to people living near flightpaths (Ingerslev, p.95).

Edmonton can boast a medium-sized airport close to the centre of the city. Its runways and instrumentation are adequate for small passenger jet planes such as the Boeing 737, thus providing a valuable service to the travelling businessman, who can avoid a lengthy taxi drive to the downtown business community. The Edmonton Industrial Airport, however, is completely surrounded by residences and, no matter which runway is being used, numerous homes are subject to aircraft noise when it is loudest: during take-off and landing procedures. Does this noise have a negative influence on the prices of affected homes? This is the question to be pursued in this thesis.

1.1 Reaction to Aircraft Noise

Noise, by definition, is "unwanted sound". Semotan and Semotanova (p.482) have described it as "any sort of sonic vibration, which may exercise noxious influences upon man or disturb him."

It could be expected that the reactions to individual annoyances should mount in tempo, through a sequence of oral and written complaints to court action as the ultimate source of redress. There have been occasions, though, when all regular channels of remedy failed or were blocked, and citizens resorted to desperate actions such as the following:

- a 100-car motorcade organized by ordinary law-abiding Long Island citizens tried to tie up weekend traffic near John F. Kennedy Airport by deliberately stalling on

key expressway ramps.

- Los Angeles mothers wheeled baby carriages onto airport runways.

- an irate citizen fired a shot at passing aircraft.

(Haar, 1968, p.556)

Spontaneous reactions of these kinds are difficult to assess and will not be dealt with in the thesis. Court decisions, on the other hand, have much better reflected the different perceptions of aircraft nuisance; they will be reviewed in some detail.

Numerous property owners have sued airport operators on the ground of property devaluation caused by aircraft flyovers. The arguments sounded convincing: an increase in noise level due to more frequent flights and larger airplanes and engines, have made the noise-affected houses less desirable to live in, thus lowering the potential resale value.

Three different tactics have been tried by the plaintiffs:

- the trespass theory
- the nuisance claim
- the just compensation tactic: taking

(Haar, 1968, pp.552-553)

Trespass Theory

When William Blackstone described the Common Law (1765 - 1769), fee ownership was assumed to include the highest reaches of air space perpendicular above the land. The proposition may not have

been intended that way, but it went unchallenged for the simple reason that no one desired to occupy air space. The aircraft brought a drastic change and the usque ad caelum theory was quickly rejected. The U.S. landmark case was United States v. Causby where recovery was allowed but the Supreme Court expressly rejected the ad caelum doctrine as to the extent of ownership. The court emphasized a distinction between realistic potential private air space use, and air space in the public domain (Haar, 1968, p.553).

Some U.S. states will afford relief where flights are directly overhead and low. As a result subadjacent owners can stop their ears with money damages while their next-door neighbors suffer.

Nuisance Claim

This route has proved full of obstacles, which have made it even less successful than the trespass theory as a basis for securing compensation. Noise, landing lights, air turbulence and smoke are ingredients of the classic nuisance, but several factors have combined to dim this promising avenue of relief. Firstly, the right to enjoy quietness is being eroded by the largely unavoidable noise of our industrial society. Secondly, the courts determine a nuisance through a balancing process: air transport has become vital to North America's economy and, therefore, the public interest weighs heavily. The third negative factor was summarized by L.M.Tondel in his report to the President's Jet Aircraft Noise Panel (1966):

> ...where a public or quasi-public enterprise, like... an airport...is expressly authorized by legislation, nuisance claims that arise out of its proper operation are to be denied.

Kaufman (p.328) has observed that, up to 1968, out of 27 military or public airport cases in which damages were recovered, only two were based on the nuisance argument. One of them was a ruling of the Kentucky Supreme Court acknowledging that noise and vibrations were "a nuisance as a matter of law if they resulted in damage to the value of plaintiff's property" (quoted in Haar, 1971, p.117).

Just Compensation: Taking

The taking claim has proved to be the most successful method in dealing with the courts. In 1970 the California Supreme Court awarded damages to some 600 property owners near Los Angeles International Airport, after it accepted the plaintiffs' claim that "...noise from jet aircraft...has resulted in a substantial diminution of the market value of these properties which thus constituted a 'taking' or 'damaging' of these properties" (quoted in Spaeth, p.413).

Many courts still reason that a taking necessitates a direct overflight, but recently there has been a tendency to abandon that logic, as exemplified by a Supreme Court of Oregon decision in 1964:

> If we accept...the validity of the propositions that a noise can be a nuisance, that a nuisance can give rise to an easement, and that a noise coming straight down from above one's land can ripen into a taking if it is persistent enough and aggravating enough, then logically the same kind and degree of interference with the use and the enjoyment of one's land also can be a taking even though the noise vector may come from some direction other than the perpendicular.
>
> (quoted in Conger, p.254)

In essence, the court ruled that the airport authority, by repeated low-level flights over private land, took out an easement and that

the owners were entitled to compensation for such taking of an easement. In contrast, a Los Angeles court decided two years later that

> ...while the noise caused by the number of jet aircraft taking off from a municipal airport and the jet engine run-ups at night...may have interfered with adjacent landowners' enjoyment of the properties, the noise was not of a substantial nature and did not cause any depreciation in the value of the properties, therefore, was not a taking or damaging of the properties.
>
> (quoted in McClure, p.82)

A follow-up inspection and study of the homes' sales history proved inconclusive indeed.

Numerous legal suits involving several hundred million dollars in claimed damages are under way, awaiting court judgments. They all will be assessed in the light of a) the reasonableness of the defendant's use of the public property (air space), and b) the gravity of the harm to the complainant (Haar, 1971, p.117).

It is evident from the foregoing discussion that accurate determination of property value loss is fundamental to a successful litigation. In 1960 the Kentucky Superior Court held that, "In the suit for damages...there must be sufficient evidence of an over-all inequity to the complainant in order to justify his submission." An authority in the field, Charles M. Haar, has concluded that there are four major reasons why many courts have not awarded adequate relief to property owners damaged by aircraft noise (1968, p.554):

1. an unwillingness to stretch traditional trespass and nuisance requirements;

2. a visceral reaction in favor of enterprise and industry;
3. difficulties in collecting evidence and the inadequacies of private litigation;
4. inherent limitations in the judicial process and enforcement.

In the course of this study only the difficulties of collecting evidence are under scrutiny. Other causes might well be more instrumental in determining judicial decisions but they appear to be of a more legalistic nature, beyond the realm of geography.

1.2 Measurement of People's Attitude to Aircraft Noise

People's behaviour in the face of aircraft noise has been the subject of numerous controlled experiments and social surveys. Apart from war times, during which aircraft have been associated with military strength, there have been few instances of the public approving of the noise. For many years complaints were received primarily from residents near airports, but the introduction of turbojet airliners brought a sharp increase in the number of people affected, and in the number of complaints. A great deal of research has been conducted to detect correlations between noise and hearing loss, sleeplessness, dizziness, lack of concentrating ability, short temper and other ailments. Most of these, in turn, were tested against physical properties of noise such as duration of sound, frequency in Hertz, occurrence, regularity, suddenness,

intensity and familiarity. A wealth of information was gained from these studies. In the context of this thesis, however, it is necessary to concentrate on the impact of aircraft noise on people's attitudes or, in other words, how people feel about the nuisance.

One yardstick of measurement is the number of complaints and legal actions against government agencies. A major survey conducted at Heathrow Airport in London found that complaints rose sharply after the introduction of commercial jet planes, but subsided in the years following, despite an increase in air traffic. It was suspected that the new noise was not only louder but also unfamiliar to the people (Wilson, 1963, pp.63-64).

A second method of assessing people's attitudes is to examine government and zoning policies. Most of these are strongly influenced by past experience with the problem of noise annoyance, and people's likely reactions are taken into account. A fine example can be seen in the Central Mortgage and Housing Corporation policy regarding financing of homes near flight paths. Based on numerous studies by the National Research Council, C.M.H.C. officials concluded that noise above the 35 NEF[1] limit impairs living conditions very seriously, no matter how much sound insulation is applied to the dwelling units (C.M.H.C., 1972, p.8). N.R.C. sociologists also conducted surveys that indicate the threshold level of adverse

---

[1]Noise Exposure Forecast, a unit employed to determine community annoyance through aircraft noise. For a more detailed discussion see pp. 31-34.

community reaction to be at about 25 NEF, while legal action and concerted group actions are certain above 40 NEF.

There is a third method of measuring people's dissatisfaction with noise: a substantial, negative difference in house prices, when compared to those of very similar but noise-free homes is a fairly good indication that people do not approve of the aircraft noise, that they fear for their health - and dollars - because of reduced demand for homes near flight paths. The reliability and forcefulness of this last method will be analyzed in this thesis.

1.3 Overview of Previous Research into Aircraft Noise and Property Value Correlations

Real estate prices have been used in several studies that tried to establish a definite correlation between aircraft noise and property devaluation. Before engaging in an analysis and constructive criticism of previous research it may be of interest to look at the results of some key studies.

One of the earliest studies was by H.O.Walther in New York and Chicago, before the era of commercial jet planes (1960). He arrived at the conclusion that

> ...airports do not affect the market value of vicinal real estate adversely... If these nuisances (associated with airports) have any adverse effects on the market value of real estate, it is either minor or it is offset by the amenities forthcoming from airports.
>
> (pp. 89-90)

De Neufville and Yajima generally confirmed this view in 1971 with a study of Chicago, Atlanta and Detroit airports. They found

that residential properties vicinal to runways initially gained faster in value than comparable houses away from airports, but less so during the 1960 - 1970 decade when the airports expanded rapidly; the effects cancelled each other (quoted in Crowley, 1972).

In 1972 Crowley examined Toronto's Malton Airport and concluded that sales prices were subject to a shock period when larger and noisier aircraft were introduced. Those depressions were shortlived, though, and prices soon adjusted to the general trend.

Cases supporting the fear of affected homeowners are less clear-cut. Conger (1968) reports about his experience as an appraiser for a Seattle court which had rewarded some 250 homeowners for damages resulting from aircraft noise. No factual information was given. Gautrin (1971) noted that London real estate agents were interviewed with respect to aircraft noise. The salesmen thought that prices of residences would climb by 5.5, 9.5 and 14.5 percent for low-, medium- and high-priced properties respectively, if the noise were eliminated. Another writer, Ingram (1972), offered the following opinion without supporting evidence:

> The effects of aircraft noise on values can be tremendous, and concern is continually mounting in government, industry and the public as to the effect on the environment and property values.
>
> (p. 423)

It was not until 1972 that the first account of an inverse relationship between noise and property values was established. Emerson found, with the help of a computer simulation programme, that the effect of 'freedom-from-aircraft nuisance' was worth 9.8

percent or $1,929 for a mean $19,683 residence (p. 274).

The only concrete evidence that noise influenced property values negatively was descibed by Spaeth, also in 1972. The 'Hall and Beaton formula'[2] (which can be attacked for oversimplification) and its successful application was the basis for a court decision in East Haven v. Eastern Airlines, where $18,400 was awarded to seven property owners near New Haven Airport.

There is a third aspect to the problem, as Walther pointed out in his comments on the New York and Chicago airports, and which appears again in his study of San Francisco's International Airport:

> From the data recorded...one must conclude that the impact of the New York International Airport on the market value of real estate in the surrounding area is very favorable...
>
> (quoted in Calgary Airport Study, IIK.i)

In other words, proximity to an airport or flight path with its associated nuisances may even enhance residential property value.

The confusion is obvious. It was, therefore, thought that a case study of the impact of Edmonton's Industrial Airport on the values of residential properties might shed some light on the problem's complexity. With the help of an improved methodology, the traditional shortcomings of which will be discussed in the next

---

[2]This formula gives a percentage depreciation of a property as a linear function of three variables: distance from end of runway, perpendicular distance from extended runway centre line and height of glide angle from the property.

chapter, it might be possible to develop a forceful, more attack-proof method of cause and effect investigation.

CHAPTER TWO

RESEARCH PROBLEM

Most research into value - noise correlations has concentrated on establishing present-day noise zones, current socio-economic conditions and a house price history dating back from 5 years (Conger) to 20 years (Crowley). The need for historic sales data has been recognized, for spot sampling could yield greatly distorted market prices due to short-term speculation and could be subjected to possibly great fluctuations which in turn could mask a long-range price trend. It is argued that these sales data should be analyzed in the light of changing social, economical, locational and noise conditions. To omit the latter variables is to pave the way for biased and/or oversimplified noise - value correlations.

2.1 Need for Historic Noise Contours

To compare historic sales data against a fixed noise zone will make it impossible to establish whether a correlation is linear or non-linear. Empirical work (Walther, 1960; Crowley, 1972) till now has presented value - year dependencies, where time took the role of noise (figure 2.1). By comparing a noisy area with a quiet district, and by plotting the difference in values or their absolute numbers on a graph, it was hoped to establish a cogent relationship.

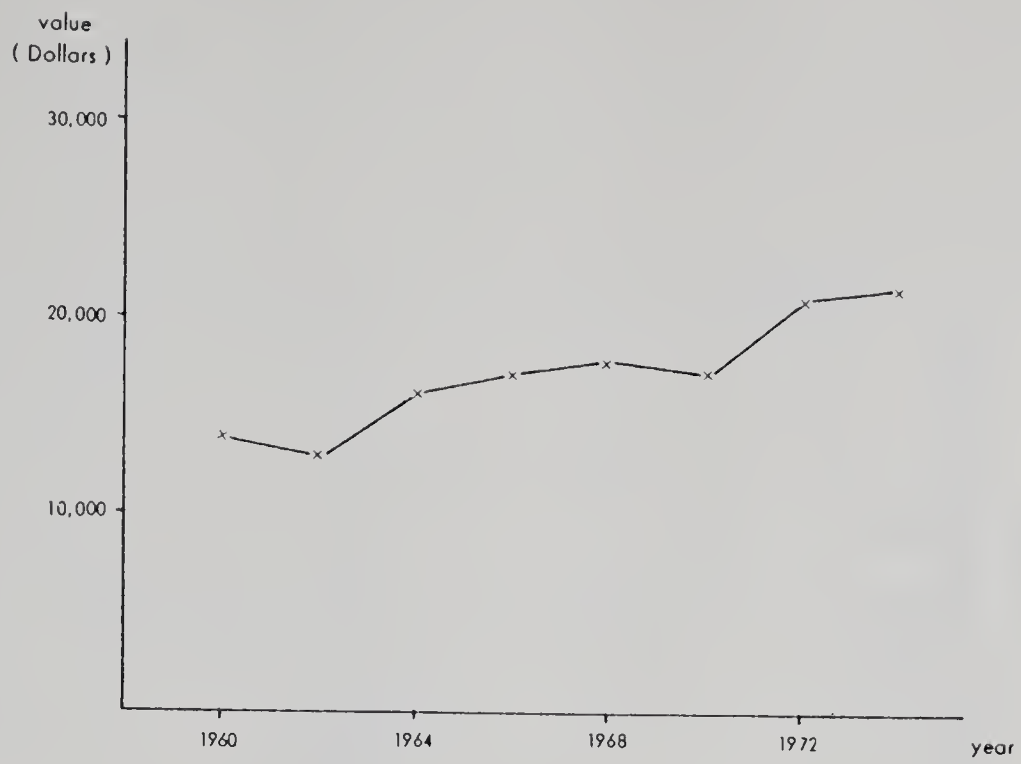

FIGURE 2.1 EXAMPLE OF VALUE-YEAR CORRELATION

The graph treats the noise as a fixed component, implying that given homes were subjected to noise of the same severity throughout the time span under consideration. Figure 2.2 gives an example of these noise annoyance contours. As shall be seen later, the introduction of a few night flights may drastically alter the contours, depending on the noise annoyance measurement used, as do new types of planes or a change in the traffic volume. It is therefore argued that noise should become the independent variable instead of time, as illustrated in figure 2.3. This graph has to be constructed for every year for which noise contours are available.

The next step is to combine value differences and noise units and determine their fluctuations over time, as shown in figure 2.4 . A simple computation will yield a $\frac{\text{value difference}}{\text{noise unit x year}}$ ratio that might

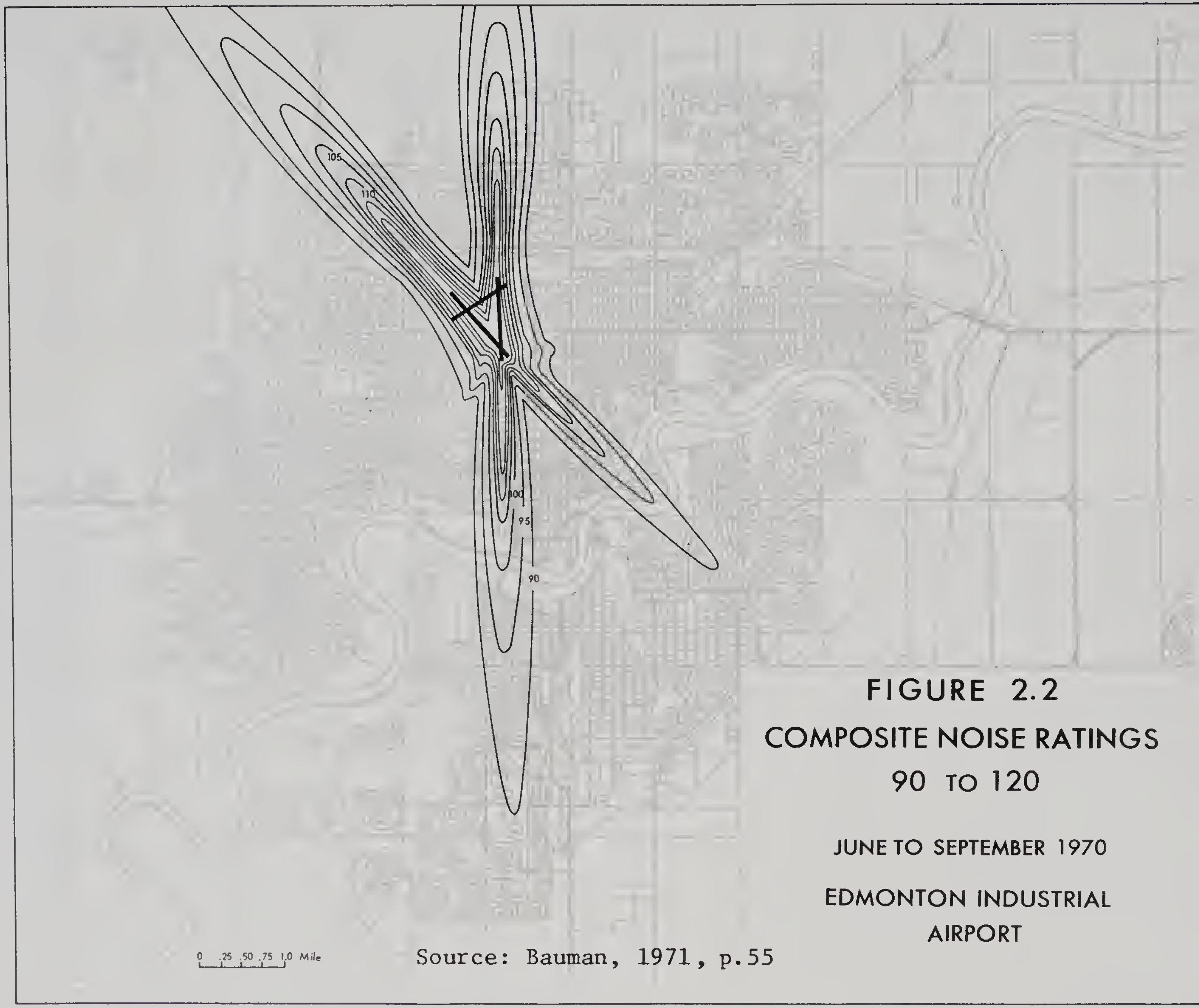

FIGURE 2.2
COMPOSITE NOISE RATINGS
90 TO 120

JUNE TO SEPTEMBER 1970

EDMONTON INDUSTRIAL
AIRPORT

Source: Bauman, 1971, p.55

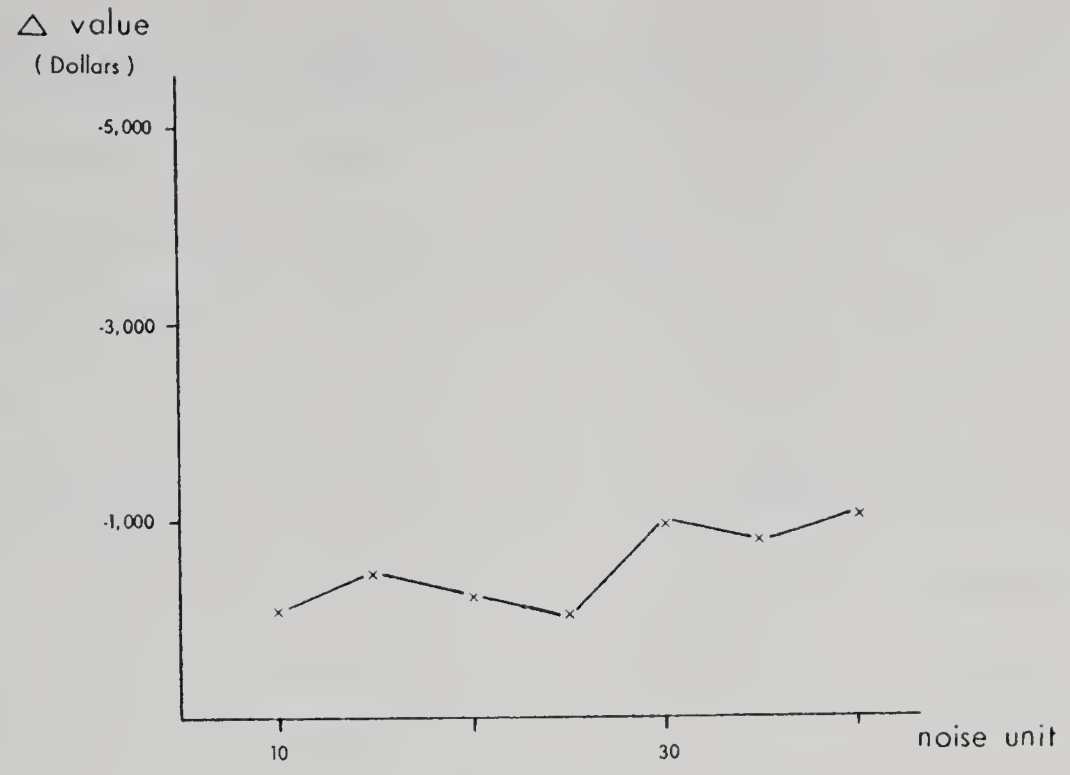

FIGURE 2.3 EXAMPLE OF VALUE-NOISE CORRELATION

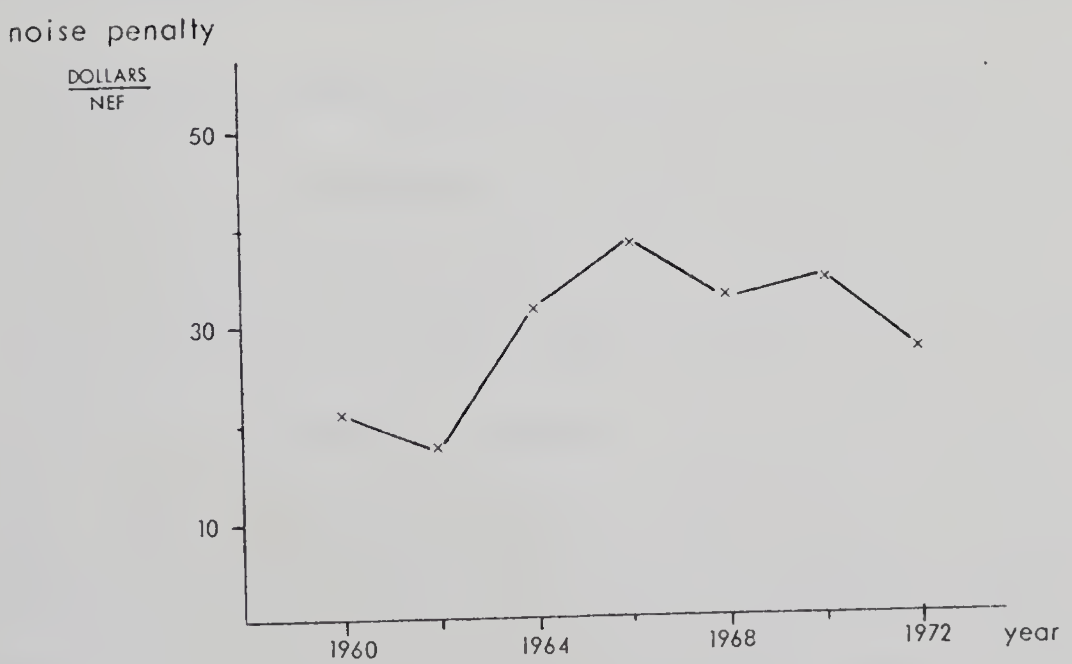

FIGURE 2.4 EXAMPLE OF NOISE-PENALTY VARIATION

be labelled the "noise penalty unit" or "noise award unit", depending on the result of the correlation. Its mathematical expression, for instance Δ $/NNI year obviously reflects the noise annoyance measure chosen. Time will be the independent variable, while 'noise penalty/award per year' (expressed in dollars) shall be dependent. It is argued that these steps account for noise intensities and variations over the years and, therefore, allow a noise-independent interpretation of trend fluctuations as suggested in the model of figure 2.4.

Unfortunately, a formidable obstacle awaits the researcher trying to construct a retroactive noise zone, let alone precise contours. Very little prior work is available on either an established methodology or on suggested techniques of securing historic data.

2.2 Need for a History of Social, Economical and Locational Variables

To obtain the best possible control areas subject to essentially the same (or very similar) locational and neighborhood conditions as the noise-affected houses, care should be taken not to neglect the possibility of their change through time. An example will illustrate the point: consider a home that has been up for sale for some time. A potential customer likes it but is deterred by the long distance to the nearest bus stop. His hesitation may propel the seller to offer the house for 5 percent less, or the client decides to look elsewhere. The effect is the same: a lack of demand will lower the price. Ten years later, under similar economic

circumstances, the owner might be able to sell the property for the asking price because the bus route has been rearranged and a bus stop is only one block away. The same house becomes literally more expensive because of improved accessibility to other parts of the city.

This example demonstrates that ideally all socio-economic and locational parameters should be the same for both the noise-affected area and its control counterpart. Whether the parameters are constant through time or move in unison is unimportant. Of the workers previously mentioned only Crowley gave details as to his socio-economic variables, but they were treated as constants.

2.3 Need for Historic Sales Data

Where real estate transactions have been reasonably frequent, sales data are quite a reliable indicator of a neighborhood's popularity. Data are readily available and lend themselves to the construction of gradients of historic trends. Many authors who tried to establish correlations between property values and adverse living conditions such as noise (Crowley, 1972; Gautrin, 1971), air pollution (Nourse, 1967) or poor accessibility to major business districts (Goldberg, 1970) have made use of the opportunity and collected sales data over a period of at least 5 years. They recognized that a spot sample of perhaps only one years was unsatisfactory.

2.4 The Importance of Time Span

A major shift in aircraft noise is almost immediately noticeable. Furthermore, official commitments and press releases on such topics as, for instance, a decision to relocate air traffic to another airport will receive wide coverage by the news media. Thus, the time-lag effect will be of small avail as far as noise is concerned. If prices react at all to noise, they will do so quickly.

Social, economical and locational variables and the consequence of their variation on property prices might be more difficult to assess but the problem can be minimized by careful selection of comparison districts. These variables largely determine the choice of the total time span as well as sampling intervals: most of the parameters are available for five- or ten-year periods only, and this clearly influences the total time period that has to be spanned. A twenty- or thirty-year time span will be more reliable as a trend indicator than will five years. In addition, it allows the inclusion of homes that may not have sold during the shorter period, homes which would have gone unrecorded over the shorter study time. To sum up: a broad historic data base, in the sense of both variance and time, helps the researcher to decide whether a certain variation is just a minor oscillation or part of a major trend.

2.5 Objectives of Study

2.5.1 Rationale for Thesis

It has been shown that there are conflicting opinions and research results reporting on an aircraft noise - property value correlation. Haar (1968) pointed at one of the main difficulties, that of securing attack-proof evidence. With some of the shortcomings of other authors' work in mind, the first goal of the thesis was established: to take into account the variable nature of social, economical and locational characteristics when forming comparison areas, and to try to devise a methodology that permits construction of retroactive aircraft noise annoyance contours. It was assumed that the introduction of new aircraft types and the shift of some flight activity to Namao and International Airports would cause a change in the noise distribution, a change well worth considering.

Edmonton has not yet been the target of a noise - price correlation study. This thesis, therefore, cannot test previous results nor can it prove that a very careful application of quantitative techniques will yield more reliable figures. Instead, the widely spread annoyance by low flying airplanes forms the basis for the first hypothesis: it is known that the City's tax assessment allows a deduction of between 2 and 8 percent, when owners of noise-affected homes complain loudly and persistently enough. They also cite depreciation as a likely consequence of the noise, a fear that has been quietly acknowledged by Tax Assessment officials. But there are no long-range studies available which would substantiate

the homeowners' depreciation argument.[1] This thesis is to fill the gap and it hypothesizes that the fear of homeowners is justified. It was mentioned earlier that court cases dealing with damage demands of several hundred million dollars are pending, mostly in the U.S.A., a point which serves to support the need for this hypothesis to be tested. It is realized that the problem is very confusing, for already in 1968 an airport study concluded that people are "...disturbed and bothered by vicinal aircraft operations even though these operations are not detrimental to their resale property values..." (Calgary Airport Study, IIK.3.). This statement, of course, is directly contradictory to the legal steps taken.

The second hypothesis is based on a questionnaire presented to homeowners: their response to detailed questions concerning noise annoyance is expected to support conclusions arrived at by analysis and interpretation of field data. More specifically, if the noise proves to be detrimental to house values, then there should be a strongly negative reaction to some of the noise annoyance questions. On the other hand, if there was a direct correlation (the noisier the environment, the sharper the price increase), then this trend should be reflected in a very low rate of buyer information through the seller. Everything else being equal, it could be expected that no one will pay more for a noisy house than for a quiet one.

---

[1]Depreciation should be understood as a relative term; thus, a slower price increase than in comparable, quiet homes would constitute depreciation.

Another questionnaire, directed at loan officers of banks and mortgage/finance companies, should also support the second hypothesis. If noisy homes have difficulty qualifying for conventional mortgages, the trend will be very clearly towards relative depreciation. By the same token, a relative value gain will be reflected in either a cooperative or an indifferent loan policy.

2.5.2 Outline of Study

Previous empirical work has had severe shortcomings, the principal one being a comparison of historical sales data in areas whose aircraft noise levels and locational, social and economical variables were treated as stable. In chapter 3 of this thesis the empirical work on noise annoyance measurement and calculation will be reviewed, and a method to determine noise annoyance contours retroactively is suggested and applied to the Edmonton scene. Social, locational and economical patterns will be shown in the next chapter, while the fifth will deal with the selection of a tool to determine property values. The results will be analyzed in the sixth chapter.

Two questionnaires will be administered to back up the findings. The first one will probe the experiences and impressions of a selected number of homeowners in the noisy area adjacent to the Edmonton Industrial Airport. The second, very short questionnaire will try to discover whether bank loan officers are reluctant to finance property under flight paths, for negative loan policies towards noise may influence house prices.

CHAPTER THREE

NOISE ANNOYANCE

3.1 Some Principles of Sound

Sound can be described as the result of a transfer of mechanical vibration to air. Sound and vibration are closely related; this can be shown by extremely powerful sounds, such as those generated by low-flying jet airplanes, that can produce mechanical vibration and structural damage to houses.

A vibrating object will disturb air molecules near it and set them in vibration; they in turn will repeat the process with neighbouring air particles. The outcome is a chain reaction of small molecular 'swings' with a definite amplitude and frequency. While amplitude is a measure of the magnitude of pressure variation, the frequency represents the number of vibrations per second, usually expressed in cycles per second (cps) or hertz (Hz). The frequency determines the pitch of a sound. For example the lowest note on a piano has a frequency of 27 Hz, the highest 4186 Hz (Anthrop, p.5).

No sound would be audible if the pressure variations within the air were so small as to elude the human ear. This organ is truly remarkable, though, in that it is able to detect sounds with intensities as low as 1×10^{-16} watts/cm^2, and yet it will endure without damage intensities of up to 1×10^{-4} watts/cm^2. In other words, the ear

will adjust to an amplitude range, where the most intense sound is 1×10^{12} or one trillion times as strong as the threshold (Anthrop, p.7).

In order to handle this enormous range of sound pressure levels (SPL) without resorting to large numbers too unwieldy to handle, a logarithmic rather than a linear scale is used for the expression of sound intensities, the unit being the decibel (dB). For instance, a reading of 1×10^{-14} watts/cm^2 means that a given sound is 100 times stronger than one of 1×10^{-16} watts/cm^2, on the human threshold. The figure of 1×10^{-14} watts/cm^2 is 20 dB higher than the threshold of human hearing.

The term loudness has been carefully avoided in the above discussion for it cannot be measured directly. Although the human ear can discern frequencies between approximately 20 and 18,000 Hz it is by no means equally sensitive across the entire range. Hearing is most acute at about 1,000 Hz and less so at lower and higher frequencies. Kryter (1959, 1963 and 1966) was instrumental in conducting psychoacoustical research, that has yielded equal loudness contours for pure tones, as perceived by test persons. However, it has been recognized that accurate determination of the judged loudness of composite tones is more difficult. Since transfer of results of pure-tone response to complex-tone conditions is hazardous, researchers have turned to signal analysis in terms of SPL for each octave or one-third octave band.

3.2 Sound Measurement

A commonly used instrument for the measurement of sound is the sound level meter. To approximate the ear's perception many such instruments have electronic weighting networks which discriminate against high and low frequencies. Most widely used is the A-weighted scale whose response coincides reasonably well with that of the human ear (Olishifski, 1968). The instrument measures the relative sound power at the receiver by comparing, in extremely short time periods, the incoming sound pressure level (SPL) with a reference sound pressure. It senses, responds to and converts pressure fluctuations, according to the following equation, almost instantaneously:

$$SPL = 10 \log \left(\frac{P}{Pr} \right)^2$$

where P = sound pressure received at meter

Pr = reference sound pressure

(CATA, CNR and NEF,p. 1-2).

3.2.1 Noise Annoyance Measurement

Kryter (1959) attempted to measure the acceptibility of sounds. He developed a linear scale to quantify perceived levels of noisiness and labelled the unit of measurement a noy. By definition, noy 1 (one) refers to the perceived noisiness of the octave band from 910 to 1,090 Hz of random noise at a SPL of 40 dB (Kryter, p. 1424). He found that sounds of equal pressure but different frequency spectra are perceived differently. Appendix A illustrates the interdependency

of SPL, frequency and noisiness in noys. The linear noy scale was then converted into a logarithmic or decibel scale and the resulting value named the perceived noise level (PNdB).

Since Kryter's results relate specifically to aircraft noise the PNdB was used extensively by researchers who were trying to measure aircraft noise annoyance. The term measure is misleading, though, because annoyance cannot be read directly off an instrument. Instead, all systems that have been developed require lengthy calculations. Before giving a short description of the methods and evaluating their usefulness for this thesis, it is imperative to list the requirements that should be imposed on a formula with claims to accuracy:

Does the equation allow correction for

- take-offs and landings, separately?
- time of engine run-ups?
- day or night operation?
- percent utilization of runways?
- number and type of aircraft?

These five points have been recognized as being intrumental in deciding whether or not aircraft are bothersome to a neighborhood (Koppe, Matschat and Müller, 1965; Purkis, 1964; Rylander, Sörensen and Kajland, 1972; Sperry, 1968), and they will be discussed in the next section. Most methods of noise annoyance computation make use of the Perceived Noise Level (PNL or PNdB) devised by Kryter, and a set of noise signatures that were constructed by Bolt, Beranek and

Newman, Inc. for each of the major aircraft categories (for an example see appendix B). Thus, important noise determinants like take-off angle, glide slope, power setting, thrust and gross weight have been considered, if only in a generalized way.

3.2.1.1 Australian System (AI)

This relies on PNdB and allows for the number of aircraft, but it does not weight other parameters. Its equation is

$$AI = 10 \log \sum 10^{L/10}$$

where L = peak value in PNdB, aircraft overhead

= number of aircraft per hour at a given measuring point

(Schaudinischky et al., p. 300)

AI is incomplete and must be rejected as a valid research tool.

3.2.1.2 British System (NNI)

The Noise and Number Index is presented as

$$NNI = 10 \log \left(\frac{1}{N} \sum 10^{L/10}\right) + 15 \log N - 80$$

(Rylander et al., p. 442)

or

$$NNI = PNdB_{max.} + 15 \log N - 80$$

(Schaudinischky et al., p. 302)

where N = number of aircraft

L = peak value of PNdB

80 = constant, covering all corrections

The maximum acceptable value for residential land use is proposed to lie between 50 and 60 NNI. Although more inclusive than AI, the British System is not yet refined enough for the purposes of this thesis.

3.2.1.3 Swedish System (EDD)

This index was developed in 1956 to determine a critical noise limit. It uses 'annoyance-equivalent day frequencies' with the definition of: number of day take-offs plus 3 times the number of evening take-offs plus 10 times the number of night take-offs (Rylander et al., p.442). The equation is written as:

$$EDD = N_{Day} + 3\ N_{Evening} + 10\ N_{Night}$$

It does not allow for other corrections. Furthermore, the EDD index is compared to a reference on the dB(A) scale, which in itself is clearly inferior to the PNdB measure, as far as aircraft noise annoyance is concerned.

3.2.1.4 French System (R)

Based on the formula

$$R = L - 16 - 10 \log \frac{960}{N} + 5 \log \xi$$

where L = PNdB, maximum value

N = traffic frequency, allowing for take-offs and landings separately

ξ = runway utilization in percent

16 = all-encompassing correction value

this system has been under criticism for its correction component of -16, which does not appear to be representative of all subjective parameters, such as day or night annoyance (Schaudinischky et al., p. 300).

3.2.1.5 German System ($\bar{Q}$)

The International Standardization Organization (ISO) has recommended the $\bar{Q}$ method as a standard measurement, thus implying its superiority to other systems (ISO, 1966). It includes numerous types of corrections in its complex formula; even the simplified equation is impressive:

$$\bar{Q} = K \log \frac{1}{T} \sum N_i \, T_i \, 10^{L/K}$$

where K = 10, recommended for planning purposes

T = specified time interval (eg. 06:00 h to 22:00 h)

N_i = number of operations in T

T_i = duration in seconds during which the signal remains within 10 dB of the maximum

L = maximum PNdB

(Schaudinischky et al., p.302; Koppe et al., pp. 251-253)

In its more comprehensive state the $\bar{Q}$ system provides for all five parameters listed earlier as being essential. Undoubtedly, the calculation will yield results exact enough for construction of noise contours, but for the purpose of the thesis it has two major drawbacks. Firstly, T_i is unknown and must be determined, for each aircraft category, through actual measurement thus posing a task beyond the research objective. Secondly, this writer does not have access to a computer programme capable of processing the $\bar{Q}$ equation. Therefore, despite the system's general suitability, it was impractical.

3.2.1.6 FAA System (CNR)

This method has found wide application in North America. The Composite Noise Rating is based on PNdB contour sets which have been generalized for various types of aircraft. Information is also required on the total number of landings and take-offs and the percentage utilization of each runway. The above data are required for each aircraft category (CATA, CNR and NEF, p. 9). CNR contours are determined with the help of the following equation:

$$CNR = PNdB + AT\ [TO/L/ER] + T1\ [DN + P + T] + ER\ [t + td + Nt] + C$$

where AT = aircraft type category

TO = take-off

L = landing

ER = engine run-up time

T1 = $\sum$ take-offs, landings

DN = day or night

P = percentage utilization of runway

t = specified time period

td = ER in minutes

Nt = number of ER during t

C = correction of CNR value for three or more CNR values within 3 PNdB of the highest

(CATA, CNR and NEF, pp. 9-16)

The formula can be criticized for omission of the flyover period, and the discreteness of 5 dB steps which might cause ambiguities in borderline cases, where a change of only one operation (eg. ER) might increase the CNR value by 5, thus placing a location perhaps under a more restrictive land use zoning. Also, there is no correction formula which can help to classify a new design in aircraft engines (CATA, CNR and NEF, p. 17).

3.2.1.7 Noise Exposure Forecast System (NEF)

The above critique has led to further studies that have culminated in the NEF method. It is based on the Effective Perceived Noise Level (EPNL or EPNdB), a PNdB that has been refined by the inclusion of signal durations and discrete frequency components (Anthrop,1973). Unlike CNR the NEF system does not use generalized contour sets to eliminate the 5-unit steps. Basic data for determining NEF contours consist of EPNdB vs. distance correlations for various aircraft groupings (see appendix C for a sample), augmented by generalized

aircraft performance data. For a given location the formula reads:

$$NEF_{(ij)} = EPNL_{(ij)} + 10 \log [N(day)_{(ij)} + 16.67\ N(night)_{(ij)}] - 88$$

while the total NEF value, at a given ground position, is then determined by the energy summation:

$$NEF = 10 \log \sum_{i}\sum_{j} \text{antilog} \frac{NEF(ij)}{10}$$

where $NEF_{(ij)}$ = NEF value produced by aircraft class i operating on runway j

$EPNL_{(ij)}$ = EPNL of aircraft class i operating on runway j

$N_{(day)}$ = number of movements between 07:00 h and 22:00 h

$N_{(night)}$ = number of movements between 22:00 h and 07:00 h

-88 = arbitrary constant as to differentiate NEF clearly from CNR

(CATA, CNR and NEF, pp. 26-27)

Most researchers who tried to establish a correlation between aircraft noise and property values have employed the standard CNR method, but this writer considers the NEF system as even better for the following reasons: firstly, NEF is more refined than CNR; secondly, it is currently being used by the Canadian Ministry of Transport in constructing sets of noise contours around all major airports in the country; and, thirdly, Central Mortgage and Housing Corporation

has defined its lending policy for new homes in the light of NEF values[1]. As a bonus the NEF computation process is available in a computer programme while a computer plotter can deliver the final contours, adjusted to scale.

One should be aware of the shortcomings though, deficiencies which are partially inherent in the other systems as well:

a) small airplanes, used privately and by flying clubs, cannot be taken into account. Because of their prevalence at Edmonton's Industrial Airport this drawback is serious.

b) the data required for NEF contours are to represent air traffic on an average summer day (CATA, CNR and NEF, p. 9). This includes a temperature of 65° - 70°F, relative humidity of 60 - 70% and no wind[2], and average summer air traffic.

c) neither NEF nor any other system provides correction for climatic variations. Wind and relative humidity are important factors governing the propagation of sound

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[1] Bauman (1971) has argued that these and other major agencies feel the factors used in the CNR and NEF systems reflect more closely the Canadian social scene than the European indices.

[2] The official description as found in the Civil Aeronautics manual does not elaborate whether the EPNdB vs distance curves were arrived at through "average summer day" measurements.

(Gracey, 1968; Ingard, 1953; Large, 1970; Parkin and Scholes, 1974) but vertical profiles of these parameters are difficult to obtain for Edmonton. Theoretically, NEF curves can be adjusted as to the predominant wind but the city's urban heat island and the numerous highrise buildings (which alter the local wind flow pattern because of turbulence) make generalization of Stony Plain data (only these are available) hazardous.

3.3 Sources of Aircraft Noise

The aircraft noise problem has chiefly become serious since the introduction of commercial jet transport in 1958. Some observers agree[3], however, that large propeller airplanes like the "North Star" and the "Bristol Freighter" were even noisier than small turbofan jet planes, largely because of their low angle of climb and the prolonged duration of the noise. To gain some insight into the nature of aircraft noise one should first look at the sources, and at the noise levels associated with landing and take-off profiles.

3.3.1 The Turbojet Engine

In jet propulsion a force is exerted by hot gases generated by the burning of fuel within the combustion chamber. The oxygen used in the burning process is taken from the atmosphere, compressed, mixed

[3]Author's discussion with air traffic controllers and flight inspectors as well as with former R.C.A.F. pilots (June 1974).

with fuel and burnt. The principal source of noise is the jet exhaust stream: exhaust gases of great velocity mix with the surrounding air, and this act of violent mixing creates the jet 'roar'. The characteristic whine of a jet engine, on the other hand, is produced by the compressor system. Most of the noise is generated behind the engines and cannot be substantially dampened by using sound absorbing material in the engine itself. However, noise can be alleviated to a good measure through a reduction in the exhaust gas velocity; as a result of this understanding the turbofan engine was developed (Anthrop, 1973, pp. 86-87).

3.3.2 The Turbofan Engine

In this design a primary jet drives a compressor and a fan. A large portion of the propulsive air drawn through the fan is allowed to bypass the combustion area (Appendix D). Both the primary jet and the fan exhaust streams provide the thrust, but the mixing of the two streams results in a lower velocity exhaust and less noise. The fan, unfortunately, introduces a new noise which is particularly audible during the landing phase, at a time of low engine thrust. Overall, the restrained gas velocities result in a 10 - 12 decibel decrease in noise at the exhaust (Committee on the Problem of Noise, 1963, p. 66).

3.3.3 The Propeller Engine

A comparison of three noise frequency spectra (Appendix E) reveals that propeller aircraft generate lower sound intensities than turbojets

and turbofans throughout almost the entire human hearing range. The main source is the powerplant and the propeller, the latter being dominant except at very low power levels. Most influential in noise generation are blade tip speed and blade setting, followed by exhaust noise (Warring, 1969, pp. 130 - 133).

3.3.4 The Turboprop Engine

In this system the propeller is driven by a turbojet. The jet exhaust contributes only 10 percent of the total thrust for it works under low power-level conditions. As a result the jet noise is far less significant than the propeller noise. For equal thrust the turbo-prop is considerably quieter than the propeller - piston engine combination. The average noise reduction is 10 decibels (Warring, p. 133). At low thrust, such as during the landing process, the compressor noise may become predominant as a high 'whine', that is especially noticeable to a listener in front of the approaching aircraft.

3.3.5 Noise Levels During Take-Off and Landing

Take-offs necessitate a much higher engine thrust than landing operations, so that different noise contours should be expected for the same aircraft type (see Appendix B). A starting aircraft usually assumes a climb angle of greater than 4 degrees, while the glide slope for large aircraft is generally between 2.5 and 3 degrees. Landing airplanes are thus lower above ground, for a given distance from the runway, than when taking off. Quieter engines yet lower

altitude have a cancelling effect, and to most people the landing noise is just as bothersome as that of take-offs. Appendix B indicates that there is, indeed, little difference in the lateral spread of noise up to 1,000 feet on either side of the flight path centre line. Wilson (1963) even observed that many people regard the whine as more objectionable than the roar of engines under full load.

3.4 Historic Approach to Noise Annoyance Contours

While property fluctuations have, on occasion, been attributed to aircraft noise influence, no actual study of historic noise annoyance contours has been conducted. This writer, therefore, proposes the following approach to the problem:

The NEF method lends itself to a close estimation of previous aircraft noise annoyance for the stipulated "average summer day" can be repeated retroactively. Although quite a subjective research procedure it is the only feasible way to reconstruct former annoyance contours. Factual information on aircraft movements is difficult to obtain and evaluate in the best of circumstances, and impossible in most cases; in Edmonton no exact records are kept for more than a few years and many past aircraft carriers are out of business.

It appears that long-time control tower shift supervisors are the best source of information. As some of them have been working at Edmonton's Industrial Airport for 15 years or more they should be thoroughly familiar with local conditions, most types

of commercial aircraft and runway utilization, as well as with the few instances of night traffic. Their memories can also be helped by supplying them with a list of the large aircraft in use at the requested times.

The accuracy of data may be tested by comparing the results of several independent interviews.

3.5 Aircraft Noise Annoyance in Edmonton

3.5.1 The Industrial Airport

The Edmonton Industrial (Municipal) Airport is located two miles northwest from Edmonton's city centre. It was selected for this study because it is surrounded entirely by single-family homes. Most of them were constructed before 1951, and only the houses north of runway 34 were built later, about 1960.

The Edmonton Industrial Airport was created, in 1924, out of the land in the New Hagmann Estate between 118 and 123 Avenues and 113 and 121 Streets, most of which belonged already to the city. Soon after the final acquisition of land, clearing commenced, and by 1927 a landing strip was prepared. Regular air traffic began in 1929 (Dale, 1969, p. 237ff.). At the outbreak of World War II the airport was sufficiently developed to allow its use as a Commonwealth Air Training Centre. From 1942 the runways were heavily used by U.S. war planes en route to Alaska and the Aleutian Islands.

Commercial air traffic picked up considerably between 1946 and 1950, and the airport saw another period of war plane visits:

U.S. aircraft stopped on their way to the Korean War (1950-1953) scene (personal conversation with several aircraft inspectors). Already in 1952 noise annoyance from the airport was a problem, mainly because of the exceedingly noisy "North Star" and "Bristol Freighter" planes. The problem was recognized in a proposed airport development plan by TransCanada Air Lines (T.C.A.) in which it was claimed that 70 percent of the noise was caused by propellers, and that the increase of jet and turbojet traffic would reduce the noise level (T.C.A., 1952).

Several attempts have been made to replace the airport with another one outside the city limits, but the existing airfield has proven so convenient and financially beneficial to the city, so vital as a supply base to Northern Alberta and the Northwest Territories, that its advantages have continued to outweigh the drawbacks (Dale, 1969). Some types of traffic (eg. the operations of C.P.Air) have been transferred to the Edmonton International Airport, which began operations in the early 1960s.

The airport has three runways: runway 03 - 21, which extends for 4,446 feet and is suitable for day operations only; 11 - 29 which is 5,868 feet long and features Medium Intensity Lighting of Type R4 (referring to background lighting so as to distinguish the runway from major traffic arterials); and 34 - 16 of 5,700 feet length, where runway 16 has Strobe Lights only, while 34 is equipped with an Instrument Landing System (I.L.S.) consisting of a light and radio beacon angled at 3° from the horizontal to guide approaching airplanes (CATA, Volume IV, pp. 1-2 and 2-1).

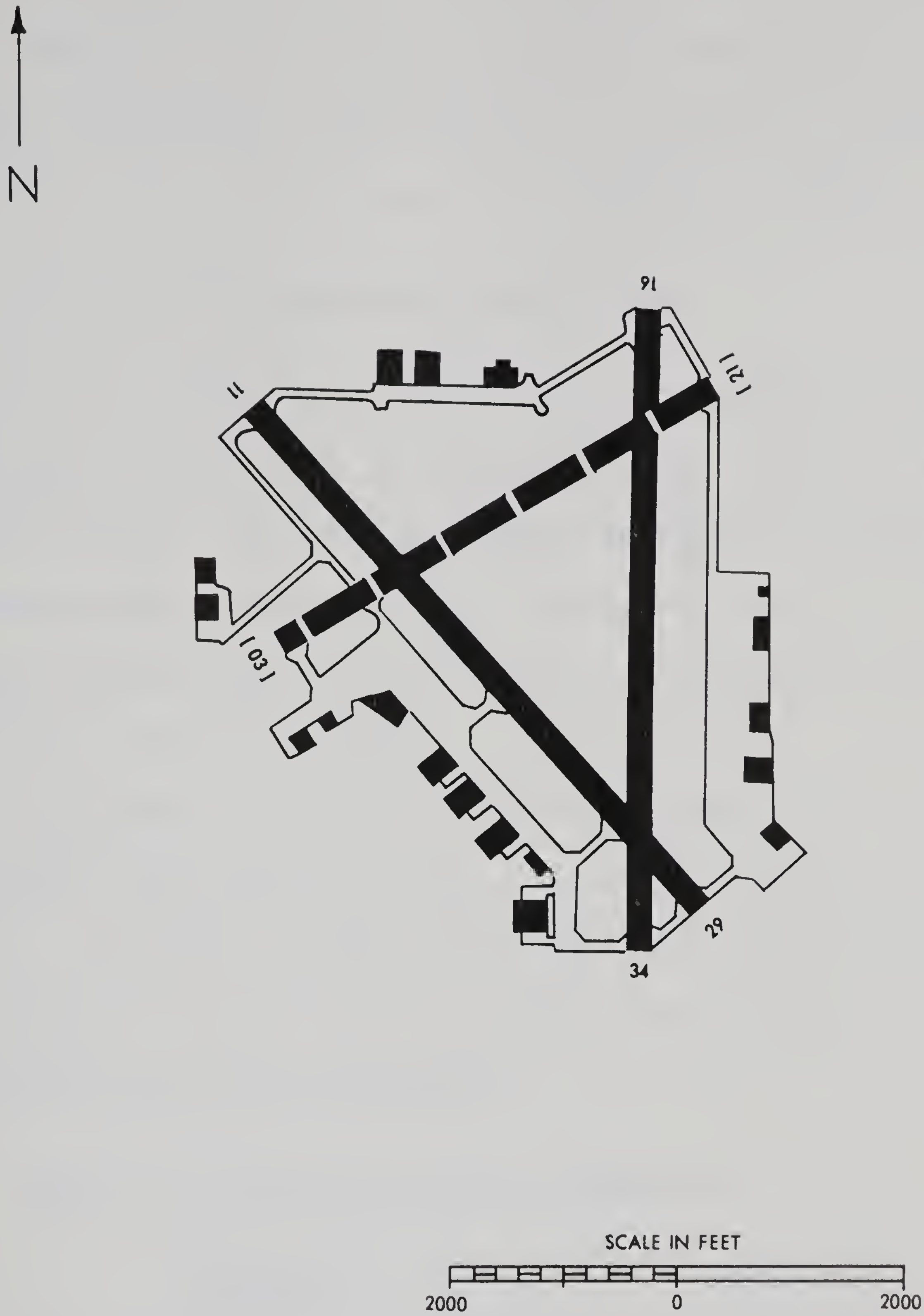

FIGURE 3.1 EDMONTON INDUSTRIAL AIRPORT

Source: Canadian Air Transportation Administration, Volume VII, Appendix E

Runway 03 - 21 is hardly used at all, certainly not by large aircraft. Consequently, only runways 11 - 29 and 34 - 16 will be considered in the construction of noise annoyance contours.

3.5.2 Construction of Noise Annoyance Contours

The NEF system (Noise Exposure Forecast) was selected as the most appropriate for this study because of the reasons outlined before (p. 32), the most important ones being easy access to computer facilities with the NEF programme in storage and the superiority to other systems (except for the $\bar{Q}$ method, which could not be adopted for technical reasons).

As pointed out earlier, the NEF system does not rely on generalized noise contour sets but uses EPNdB vs. distance functions based on generalized aircraft performance data instead. These functions (see appendix C for an example) are available for the following airplane type categories:

Table 3.1 NEF System Aircraft Categories

Category	Code Number
Four-Engine Turbojets	01
Four-Engine Turbofans	02
Two- and Three-Engine Turbofans	03
"New Generation" Four-Engine Turbofans	05
"New Generation" Three-Engine Turbofans	06
Business Jets	08

Four-Engine Propeller Types	09
Two-Engine Propeller Types	11

(CATA, CNR and NEF, p. 21)

This grouping is incomplete but it allows most retired aircraft types to be categorized, even though their noise measurements were never taken. The computer programme allows, in addition, for adjustment to extremely noisy or quiet airplanes within a category.

3.5.2.1 General Process of Determining NEF Contours

In calculating NEF at a specific location, the contribution in EPNdB's from each aircraft operating from each runway is determined by measuring the distance from the ground point in question to the aircraft, and then obtaining EPNdB values from the corresponding EPNdB vs. distance curves (appendix C). The noise contribution from all aircraft categories operating on all runways are then summed up in an energy formula (p. 32) that gives the total noise annoyance. NEF values are determined strictly through a numerical calculation procedure, and the large number of computations means that computer techniques provide the only practical way of constructing contour sets.

3.5.2.2 Historical Noise Annoyance Contours

To determine the earliest feasible date for noise annoyance contours it was decided to use social and neighborhood characteristics and their availability as a guide. It was found that although census data were taken earlier, Edmonton was not subdivided into census

tracts until 1956. Before that date the city was divided into four or five large districts, too large and general for the purpose of this thesis. 1956 was, consequently, chosen as the earliest date for retroactive noise annoyance contours, and for the social, locational and economical determinants as well (discussed in the next chapter).

In the absence of an established method this author proposed his own mode of constructing historical noise annoyance isolines, as suggested before (p. 37). Commercial carriers, it was found, do not keep records of aircraft movements for more than three years, while government agencies do not have detailed information from the years before 1968. The search for "old-time" air traffic controllers, however, proved to be successful: the two men selected had been in charge of their respective shifts from 1958 to the present and from 1949 to 1967 respectively.

The two men were asked to record all scheduled aircraft of a typical summer day in 1955, 1960 and 1966. After the first man had given all the movements of large aircraft he could remember, the second one corrected and complemented the lists. It was found that very few corrections were needed. The controllers did not require a list of aircraft to aid their memory, for they designed their own list with help of historic events such as the opening of Edmonton's International Airport and the consequences to the Industrial Airport; the transfer of military airplanes; the relocation of C.P.Air; and the construction of the C.N. office tower. The two controllers' estimate of air traffic corresponded closely with each other; this

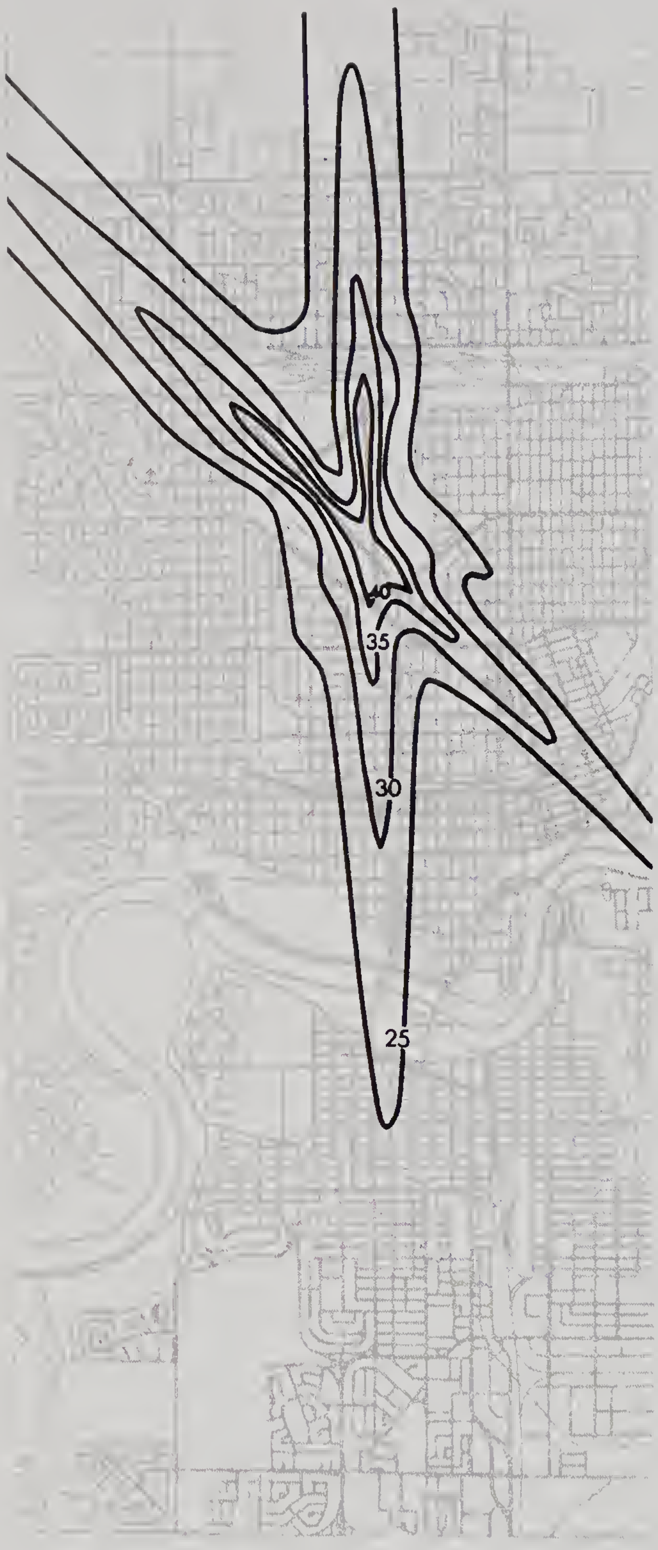

FIGURE 3.2
NEF CONTOURS IN 1955

Source: Author's Interviews

FIGURE 3.3
NEF CONTOURS IN 1960

Source: Author's Interviews

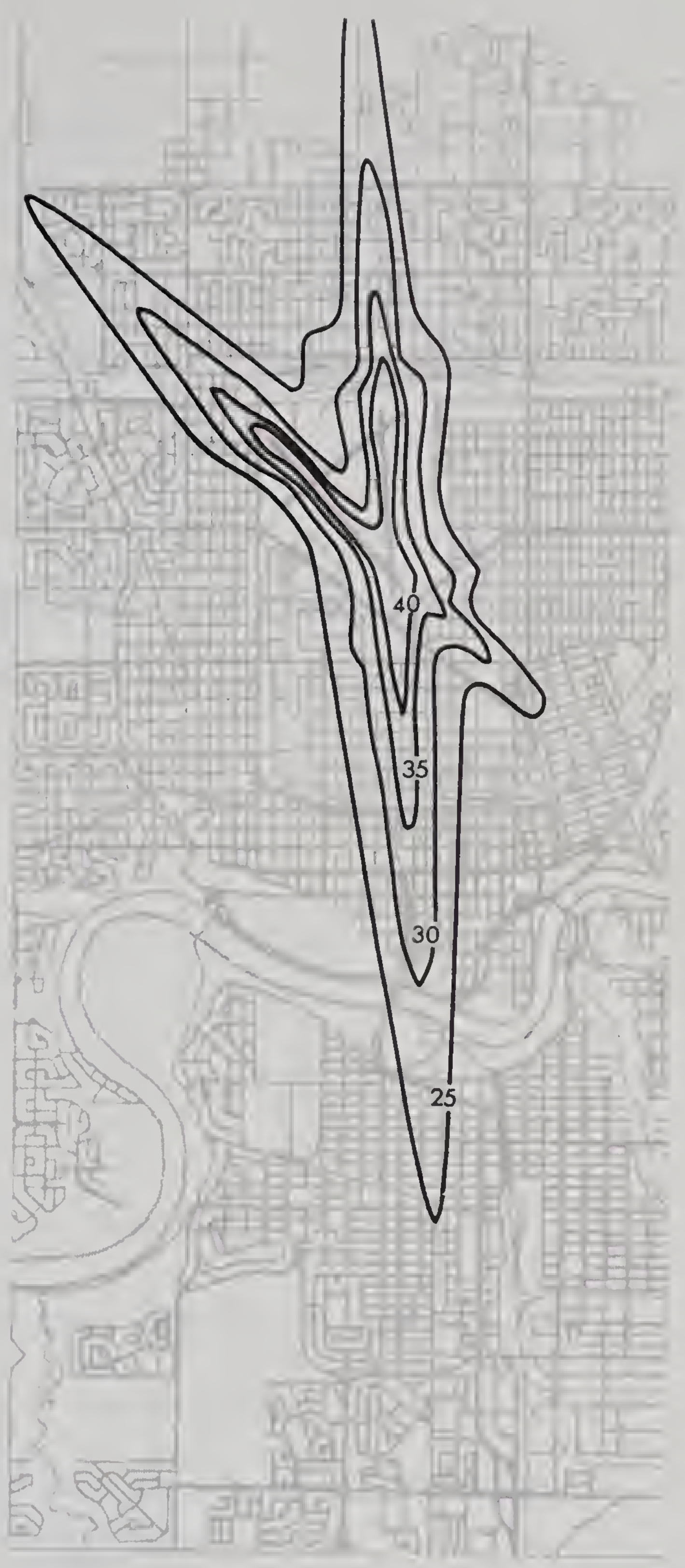

FIGURE 3.4
NEF CONTOURS IN 1966

Source: Author's Interviews

FIGURE 3.5
NEF CONTOURS IN 1971

Source: Canadian Air Transportation Administration, 1971

fact and their detailed knowledge of aircraft types, the phasing-out dates of airplane types and the introduction of new ones, and their excellent recollection of the interdependence of flight patterns and local historic events, suggests a good degree of data reliability.

The results are shown in appendices F - H, where column 5 is the aircraft code (see table 3.1; needed by computer) and column 12 indicates the day and night flight proportion. Columns 6 to 9 reveal the relative importance of each runway with respect to day/night ratio and frequency of usage. The last parameter had to be generalized for all aircraft categories.

Table 3.2 Runway Utilization for 1955 and 1960

runway :	29	34	16	11
utilization:	50%	30%	15%	5%

(estimate by B.Smith, control tower shift supervisor)

With the completion of the CN tower in 1966 pilots of large aircraft avoided runway 29 whenever possible, for the building is over 250 feet high, yet only 1.6 miles away from runway 29. Utilization therefore changed, as demonstrated in table 3.3:

Table 3.3 Runway Utilization for 1966 and 1971

runway :	29	34	16	11
utilization:	30%	50%	15%	5%

(estimate by R.Rohr, Civil Aviation Branch, Edmonton)

These figures are based on accurately determined 1971 data and have been generalized for 1966; they assume that no change in runway use

patterns took place between those dates.

The information shown on the work sheets (appendices F - H) was used in the computer programme, which in turn fed a computer plotter that produced noise contours at true scale. These NEF contours are shown as figures 3.2 to 3.5. The contours represent, therefore, areas of equal aircraft noise annoyance. It should be pointed out that the fourth set, figure 3.5, was already prepared by the Civil Aviation Branch in Edmonton, and was adopted into the thesis from its publication CATA, Volume VII (p. 52).

3.6 Discussion and Critique

Figures 3.2 to 3.5 show the noise annoyance patterns for 1955, 1960, 1966 and 1971. An examination of their contours reveals interesting trends.

Noise annoyance was worse in 1955 and 1960 than in 1971 while 1966 proved to be the quietest year, by far, mainly because air traffic was sharply reduced: 62 daily movements versus 108 and 124 movements for 1960 and 1955 respectively. By 1966 military airplanes were using Namao Airport almost exclusively and C.P.Air had relocated to the International Airport. In addition, the Calgary - Edmonton airbus service was begun after 1966, and its effects are visible on the 1971 noise annoyance pattern.

The south-east leg of the contours became progressively unimportant, largely because numerous high-rise buildings in the downtown area began to obstruct flight path 29. The sharpest decline was from 1966 to 1971 (1966 was the completion year of the CN tower).

The north-west leg was very pronounced in 1955 and 1960, and lost from 1966 on in its areal extent. The explanation should be sought in the change of aircraft types; slow-moving and slow-climbing propeller planes were commonly used in those years, but by 1971 they had been largely replaced by turboprop engines of quieter operation and by fast jet planes that climb at a steep angle.

The south leg is the only part of the noise annoyance contours that had increased in size in 1971; the principal reason is that aircraft switched from runway 29 to 34 for the safety reasons mentioned above. Another contributing factor is the increase in airbus traffic between Calgary and Edmonton; this is concentrated on the south - north runway.

The northern leg of the contours is stable throughout the years; it appears that the jet planes' steep climb angle and subsequent noise reduction on the ground is offset by their preference to take off from runway 34.[4]

The NEF method is vulnerable to criticism; even if exact data about aircraft movements could be obtained, the selection of a "typical summer day" is in itself subjected to a strong bias, for no control is possible to assure the researcher that a chosen day was indeed representative. Further, apart from neglecting

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[4]This seems to be the only plausible explanation. Generalized runway utilization data do not allow a detailed analysis.

meteorological data which might influence sound propagation, the NEF system does not account for small, light aircraft. Their EPNdB vs. distance curves have not been prepared as yet, but there is little doubt that their sheer number and frequent movements could irritate some residents more than the occasional, but much louder jet plane. This intuitive expectation was supported in the questionnaire responses: 42 percent of the respondents indicated that light airplanes were more bothersome than big ones.

To sum up: the interview technique was the only feasible approach to construct retroactive noise annoyance contours. Data reliability was judged good. The forced omission of meteorological data is difficult to assess as to its impact on the longitudinal or lateral spread of the various contours. However, the NEF system's shortcoming regarding light aircraft is considered a serious drawback. Despite these faults the Noise Exposure Forecast is a reasonably accurate method of noise annoyance determination, and one of the best available.

CHAPTER FOUR

SOCIAL, LOCATIONAL AND ECONOMICAL VARIABLES

4.1 Influence on House Prices

Considerable effort has been spent on the identification of residential land value determinants. Parameters proposed range from school quality to accessibility of the central business district (CBD), from lot size to the 'right' church and from absence of aircraft noise to a nice view. Classification of the variables makes it possible to divide them into three categories:

- characteristics specific to the property
- location characteristics
- neighborhood characteristics

Ridker and Henning (1967), for example, have used this grouping in their effort to determine the effect of air pollution on residential property. They introduced about fifteen variables deemed to be important into a regression analysis and found that substandard housing, crime rate, CBD accessibility and school quality were most significant. In 1972 Emerson observed that features having a positive influence on values were proximity to open space, freedom of nuisances normally associated with corners and arterials, and lot size. Values were depressed because of urban freeway proximity, high

levels of aircraft noise and closeness to schools and bus stops. In another study it was shown that accessibility explains a great proportion of the value variation of residential land, but the relationship was largely concealed because very low amenity levels were found in areas of highest accessibility (Brigham and McAllister, 1968). Another worker, M.Gottlieb (1965) employed a regression analysis on a Milwaukee case and concluded that average family incomes were quite important, more so than relative lot supply, assessment bias or "speculative activity variables" (pp. 14-15). Comparing land values on the basis of lot size alone Ritter (1971) argued that size certainly has a bearing on the sale prices; but he pointed to the need to compare relatively homogeneous categories of lot size. On the other hand, Cooper[1] reasoned that small lots keep otherwise similar properties lower in value than those with a normal-sized lot, but that the relative price fluctuations over time would be the same.

Among the researchers reporting on aircraft noise vs. property value several mention the use of social and locational variables in securing proper control districts but only Crowley gives some detail. His choice of variables consists of similar distribution of population density, similar age of houses, equivalent accessibility to downtown shopping areas and to highways and arterial roads, and a

[1]Supervisor for land assessments, Assessor's Department, City of Edmonton. Personal communication in June 1974.

dummy variable for unspecified influences. Instead of using those factors in a regression analysis Crowley looked for near-identical areas, thus eliminating the need for ranking of importance.

The significant lesson to be learned from other research is that no single parameter is consistent in controlling residential value trends. The dominant variable seems to change with each case study.

As a consequence this writer suggests that Crowley's model of searching for identical areas is well suited, where highest accuracy is demanded. But it should be expanded in its data base, using perhaps Ridker and Hennings selection (p. 246ff.) instead. The assumption is that identical (or nearly so) socio-economic and locational parameters, that have changed in unison throughout the study period, cease to be instrumental in price difference variations. Sale prices do not have to be the same but the relative difference between the prices of a noisy area and its control district should not change because of socio-economic and physical variables other than aircraft noise.

It was decided to use Ridker and Henning's variables as a model:

- median number of rooms per housing unit
- percentage of houses recently [sic!] built
- total number of homes per square mile
- time zones, divided into bus travel times to CBD
- school quality
- occupation ratio

- highway accessibility
- persons per housing unit
- median family income
- shopping area accessibility
- industrial area accessibility
- crime rate
- percentage of housing being substandard
- percentage non-white housing units

(p. 246ff.)

Some of these parameters do not apply to the Edmonton scene while others, relating more directly to noise, might be added, depending on data availability.

4.2 Selection of Pertinent Parameters

The hypothesis that aircraft noise depresses residential property prices can only be proven if one is assured that sale price variations from one part of the city to another is not caused by determinants other than noise. The noise-affected and the control area should, therefore, be as similar as possible in their social, economical, locational and physical composition. As a useful rule of thumb an analysis should include all variables that are likely to be at least as important as the variable of primary interest; it is then unlikely that the primary parameter will prove to be significant only because it happened to be correlated with some more important factor left out of the analysis.

With the a priori expectation that the impact of aircraft noise annoyance on property prices was likely to be small relative to other determinants, the following parameters were selected (not in order of importance):

Property characteristics

- age of homes
- average number of rooms

Locational characteristics

- shopping centre accessibility
- proximity to bus route
- car travel time to CBD
- bus travel time to CBD

Neighborhood characteristics

- families with three or more children
- average family income
- crime rate
- freedom of truck noise
- obnoxious odors
- emissions
- persons per household

The list relies to some extent on that of Ridker and Henning, shown earlier. Parameters such as school quality, occupation ratio and percentage of non-white housing units were impossible to determine; the last factor, together with highway and industrial area accessibility, was deemed rather unimportant for Edmonton's house prices. Other possible influences on house prices, which might even

involve detrimental living conditions were included in the list; they are obnoxious odor, emissions (pollutants) and traffic noise.

In any case, parameters to be selected had to be available, manageable and quantifiable for all of Edmonton, for the aircraft noise-free control districts could be located anywhere in the city. Failure to comply with those prerequisites resulted in the factor's exclusion.

4.3 Critique of Parameters Rejected

A discussion with real estate agents will reveal that many home buyers are concerned about schools for their children, that is about their quality and accessibility. Ridker and Henning who had school data avilable for their St.Louis study found them to be quite significant, especially among higher-priced houses. Similar information was not available for Edmonton, and the possibility of interviewing real estate agents was discouraged by a researcher for the Public School Board, who argued against them on grounds of their high turn-over rate and bias.[2] School quality is difficult to measure objectively, and only two systems of quantification are easily applied for large-scale surveys. One is the average score on a standard reading achievement test for pupils in the third and fourth grades, while the other is based on the overall student to

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[2] Dr. T.Blower, research director for the Edmonton Public School Board. Telephone conversation, June 1974.

teacher ratio (King, 1973, p. 92). The latter criterion was rejected as extremely biased and not representative, while the reading test results for Edmonton could not be obtained. Those results, even if they were published, might not even influence a parent in his house purchase decision, for it is argued that the effect of their children's 'recommendation' may carry more weight, even if their advice is based on subjective aspects like friends, a lenient principal or a good hockey programme.

Closeness to schools is another selling point but only for families with children. Emerson (1972) found that proximity to schools was considered a nuisance; his regression tables suggested that a residence 1,000 feet away should sell for 3.7 percent more than an identical house only 100 feet away. The main reason why this parameter was left out was the difficult and time-consuming process of comparing residential patterns with those of public, separate and private schools. It was judged that the effort was not justified in face of a hazy correlation, that might even be cancelled by older residents in the same area who prefer to live away from schools to avoid pranks, noise, littering and other nuisances usually associated with school children.

Another rejected determinant was the occupation ratio, one of the components in the Shevky-Bell social area index. According to these authors it indicates, for example, the ratio of craftsmen, labourers, foremen and operatives to the total number of employed persons (Shevky and Bell, 1955, p. 54). The assumption is that people, in general, prefer to live in neighborhoods homogeneous

with respect to broad social and occupational classes. Lack of data excluded this index.

There are many other parameters that could become important such as proximity to work, the layout of a house, zoning changes, closeness to friends and relatives or access to a frequently used highway, to name just a few. It becomes evident that most of these could only be quantified by detailed interviews or questionnaires. The difficulty of locating former homeowners and the time and expense involved excluded these parameters.

4.4 Choice of Mapping System

The expected data had to be organized to allow trends and patterns to be discerned and, more importantly, facilitate the selection of matching noisy - noise-free areas.

The reader will notice the irregular shape of the Edmonton base maps. It outlines the city's boundary of 1956 and it was deemed advisable to maintain that outline throughout the study period, to avoid confusion and to maintain a homogeneous impression. Since all potential control areas had to be already within the 1956 boundary, there was no point in updating the city outline with each new control year.

Most socio-economic variables in Edmonton are available according to census tract. However, the latter's large size and often irregular shape, repeated subdivision and an inconsistent numbering makes an alternative to census tracts very desirable. The mapping system should consist of units small enough to reflect

the values of distinct neighborhoods, yet not too small to be overly sensitive in the face of rather crude scales of social, economical and locational variables. Also, the system should be designed to allow multiples of units to fit within Edmonton's major arteries, for these often form "natural" boundaries between neighborhoods. It was decided to use the one-half mile square (quarter section) as the most appropriate unit. Since Edmonton is laid out, roughly, in a grid system and most important arteries parallel each other at intervals of one or two miles, a finer grid network of .5 by .5 miles was deemed suitable. Grid squares of equal size can easily be compared and make ranking of the parameters' importance with help of a regression analysis superfluous.

In this thesis the attempt will be made to compute similarity indices that will determine "discrepancy numbers". Their values for the grid squares under flight paths and aircraft noise zones will then be compared to grids of areas not affected by aircraft noise. The best-fitting pairs will then be examined for property price trends.

The grid square, and the adopted comparison technique similar to Crowley's (1972), will overemphasize finely coded and possibly less important parameters, while broader-scaled variables may be underrepresented. In areas of identical patterns this criticism is immaterial or, at the most, of small significance; but when values differ from one grid square to another, the researcher should account for the potential consequence to house values by applying his own judgment.

At this point a critical note on the control years may be in order: it is admitted that there is a slight difference among the years, particularly between NEF contour dates and those of socio-economic and locational variables. The flight years of 1955 and 1960 were slightly off the census tract years of 1956 and 1961 for the following reasons: a confused, temporary flight traffic situation in 1956 (partial relocation to Namao Airport) and 1961 (C.P.Air relocated to the newly opened International Airport) would have distorted regular flight patterns. Ideally the noise contour and census years should have been the same; however, a variation of one year was judged insignificant. Also, not all of the parameters could be examined in the same control years; the obnoxious odor complaints, for example, were categorized for the first and only time in 1973, two years after the census year 1971.

4.5 Property Characteristics

For lack of data only the age of homes and number of rooms per dwelling unit were included in the survey. Outward appearance was omitted at this stage, but was accounted for later.

4.5.1 Age of Homes

The bases for determining this parameter were the Edmonton land use maps for 1954, 1961, 1965, 1968 and 1972 and a physical expansion map prepared by the assessor's department, showing stages of development from 1921 to 1971, in ten-year intervals. Tabulating

and coding were arranged in the following manner:

age	code
0 - 5 years	1
6 - 10 years	2
11 - 15 years	3
16 - 20 years	4
>20 years	5

The slight discrepancies between age and noise annoyance control years were believed insignificant. Figure 4.1 depicts the pattern of this parameter. To explain the pattern is not very enlightening, for the first control year predetermines the picture in the later years. It can be seen that the oldest houses are found in the area between the North Saskatchewan River and the CBD, between the river and Whyte Avenue, in the Norwood and Woodland area and along 124 Street north of the river. Some outlying districts are in North Edmonton (Q 15 on the grid) and Calder (Q 7-8).

4.5.2 Number of Rooms per Dwelling Unit

The average value for this determinant was 5.0 in 1961 and 5.4 in 1971; therefore, rather than using absolute figures it was decided to compute and map relative deviations from average values. The survey is conducted by Census Canada only every ten years and, consequently, the figures were interpolated for 1966 and extrapolated for 1956. The most favorable conditions are found in the southwest of the study area, where they coincide with the highest-income pattern

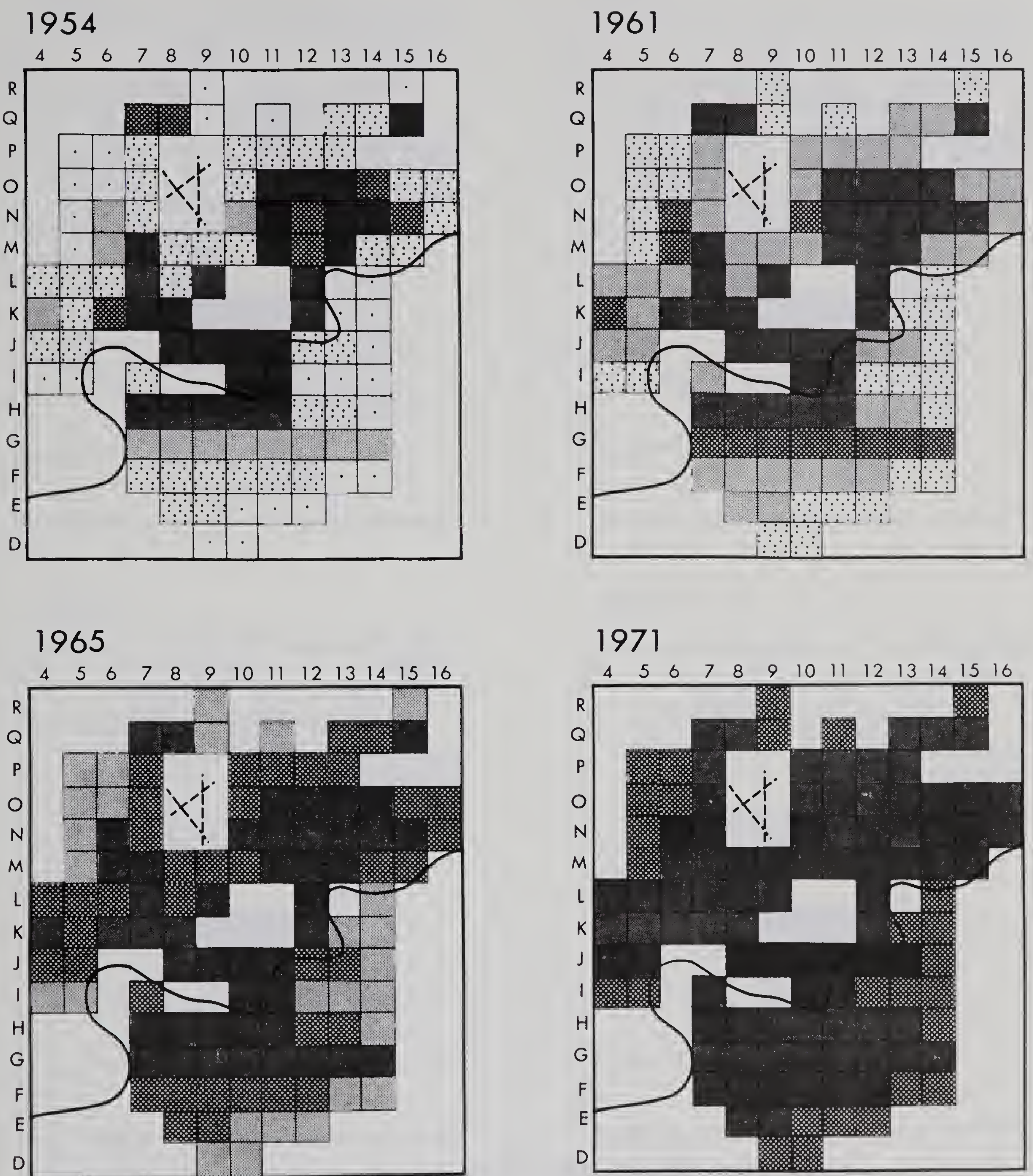


FIGURE 4.1 AGE OF HOMES

0-5 years
6-10 "
11-15 "
16-20 years
> 21 "

Source: City of Edmonton Assessors Department
Edmonton Land Use Maps

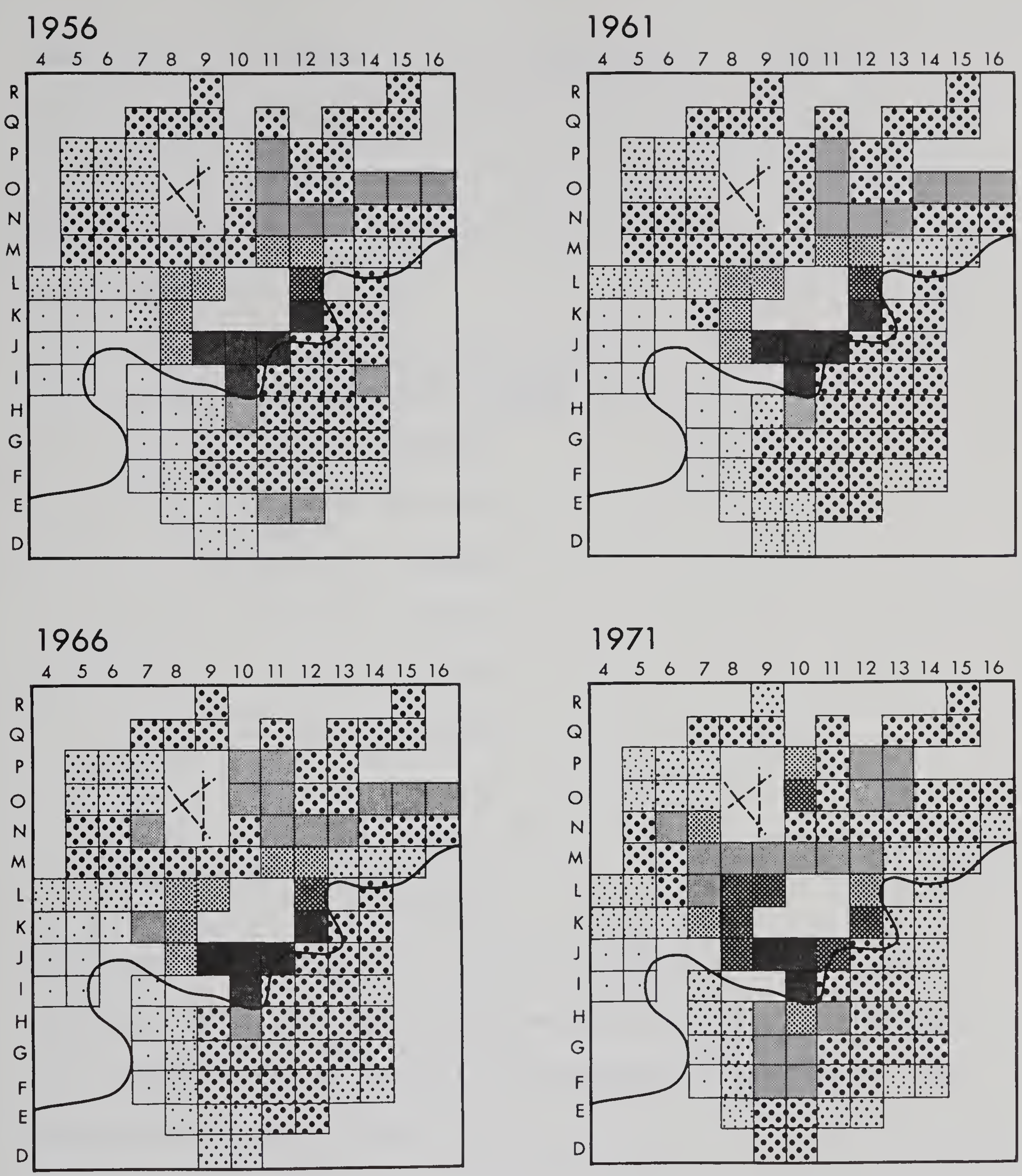
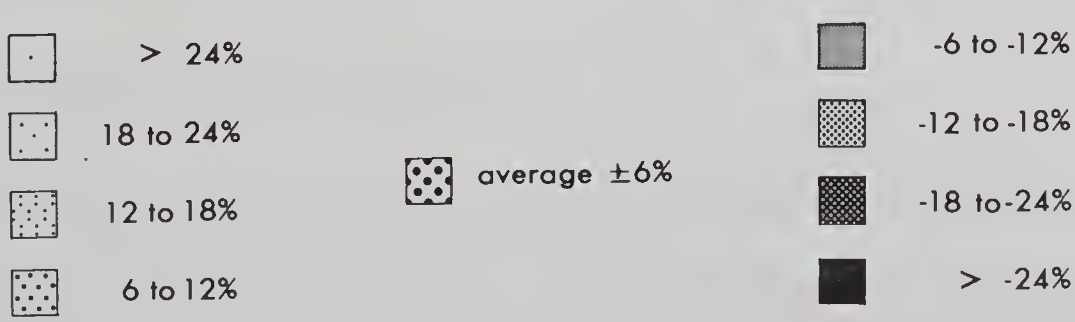


FIGURE 4.2 NUMBER OF ROOMS PER DWELLING UNIT
DEVIATION FROM AVERAGE



Source: *Census Canada*

shown later. The regions with the lowest number of rooms are usually those containing many highrise apartment houses. The deviations from average spanned a total range of about 50 percent, and a breakdown of this range into 9 sub-ranges was considered appropriate:

number of rooms per dwelling unit (deviation from city average)		code
$>+24$	percent	1
18 to 24	percent	2
12 to 18	percent	3
6 to 12	percent	4
-6 to 6	percent	5
-6 to -12	percent	6
-12 to -18	percent	7
-18 to -24	percent	8
>-24	percent	9

In retrospect it appears that there were too many classes which, because of the grid comparison system, place an unduly heavy weight on a variable, that is judged to be relatively insignificant. The patterns are shown in figure 4.2.

4.6 Locational Characteristics

4.6.1 Shopping Centre Accessibility

It was decided to concentrate on the eight regional shopping centres, for the small neighborhood centres tend to follow the concentration of

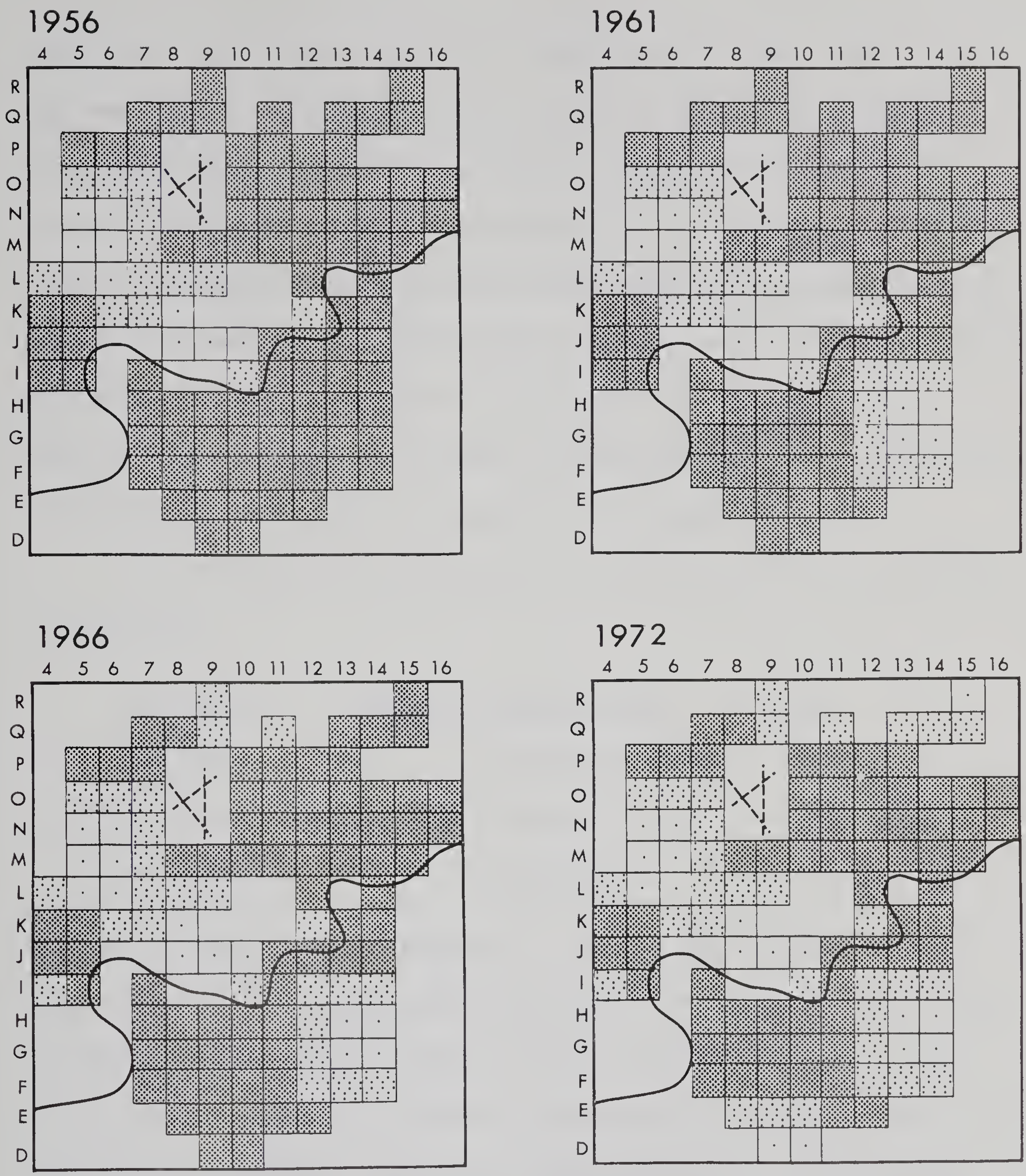


FIGURE 4.3

WALKING TIME TO REGIONAL AND DOWNTOWN SHOPPING CENTRES

< 10 minutes

> 20 minutes

10 to 20 "

Source. H - W. Mary ,1974

populations just as do elementary schools and churches. The regional types, however, are often located in sparsely populated areas where large tracts of land can be secured relatively cheaply, and with the least population displacement. In an automobile society, regional shopping centres cater primarily to customers with their own transportation. Proximity to such a centre could, therefore, be regarded a selling point only for people who have to walk for their purchases, who avoid taking a bus and who are not satisfied with the limited choice offered in neighborhood stores.

On the basis of this assumption, accessibility was classified in this way:

distance	approx. walking time	code
$<$0.5 miles	10 minutes	1
0.5 - 1 miles	10 - 20 minutes	2
$>$1 miles	20 minutes	3

Walking time was computed generously to allow for the slow pace of older people. It is speculated that many of them like to live close to shopping amenities for lack of a car. As said, figure 4.3 does not take into account the numerous neighborhood shopping centres interspersed throughout the city. Close proximity to one of them, it is agreed, could be as important a selling point than nearness of a regional or the downtown shopping centre.

4.6.2 Proximity to Bus Routes

Emerson (1972, p. 272) noted that close proximity to bus traffic is,

on the whole, a source of nuisance. The nuisance factor, notably deceleration and acceleration noises as well as waiting people littering the front lawns, has also been acknowledged by the City Assessor's Department for it allows deduction of the assessed value. This writer, consequently, excluded all roads (and their houses) with bus traffic from further consideration.

The nuisance changes rapidly into an amenity only one block away from a bus route, a location very desirable to people dependent on public transport. With this in mind a system was devised that penalizes an increase in distance, yet allows easy classification. Information could be obtained for 1953, 1957, 1960, 1966 and 1972. The first two years' values were interpolated to get the 1955 data.

bus route	approx. walking time	code
bus route leading right through centre of grid square	<5 minutes	1
route touching a grid square	5 to 10 minutes	2
route less than 0.5 miles from square centre, not touching	10 to 15 minutes	3
route more than 0.5 but less than 1.0 mile from square centre	15 to 20 minutes	4

The code pattern is shown graphically in figure 4.4. The general trend appears to be a reduced walking time, but the conclusion could be misleading. While Edmonton's boundary, as shown in figure 4.4, reflects the situation of 1956, the formerly outlying and sparsely served areas had, by 1971, become absorbed in built-up surroundings. An extended survey conducted within the 1971 boundary would probably show that the new outlying areas are sparsely served as well.

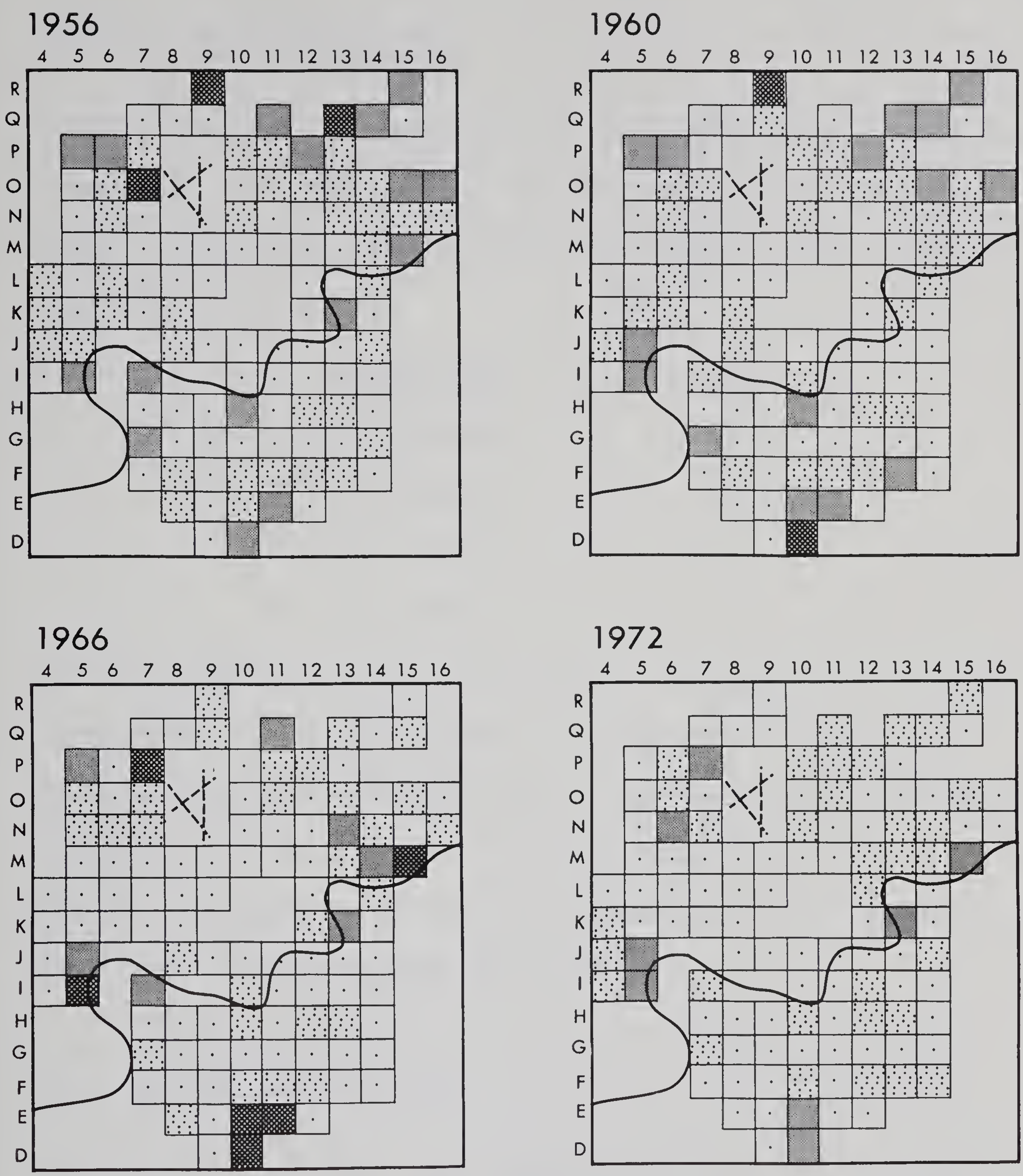


FIGURE 4.4

WALKING TIME TO BUS ROUTE

< 5 minutes

5 to 10 "

10 to 15 minutes

15 to 20 "

Source: H-W. Mary, 1974

4.6.3 Car Travel Time to CBD

The City Transportation Department has prepared contours of equal travel time to the CBD, and the data were utilized in the present study. The times were available for 1961, 1966 and 1972. The code for 1955 was extrapolated:

travel time	code
<5 minutes	1
5 - 10 minutes	2
10 - 15 minutes	3
15 - 20 minutes	4

Figure 4.5 reflects the resulting pattern. It barely varies over the study period. The most remarkable trend appears in a travel time reduction from the northeast of the city, and an increase from the northwest. 1966 is particularly interesting for it brought a temporary worsening of the travel situation from southern Edmonton, and a slight improvement from the northwest.

4.6.4 Bus Travel Time to CBD

Contours for this variable were available for 1961, 1969 and 1973, making inter- and extrapolation easy. The bus travel code was similar to that for car travel time, and it did not include waiting periods. Figure 4.6 shows that a considerable area of the city requires over 30 minutes bus travel to reach the CBD, while there was none for car travel. It is interesting to note that the area of short travel time (up to 15 minutes) shifted from East-Edmonton in

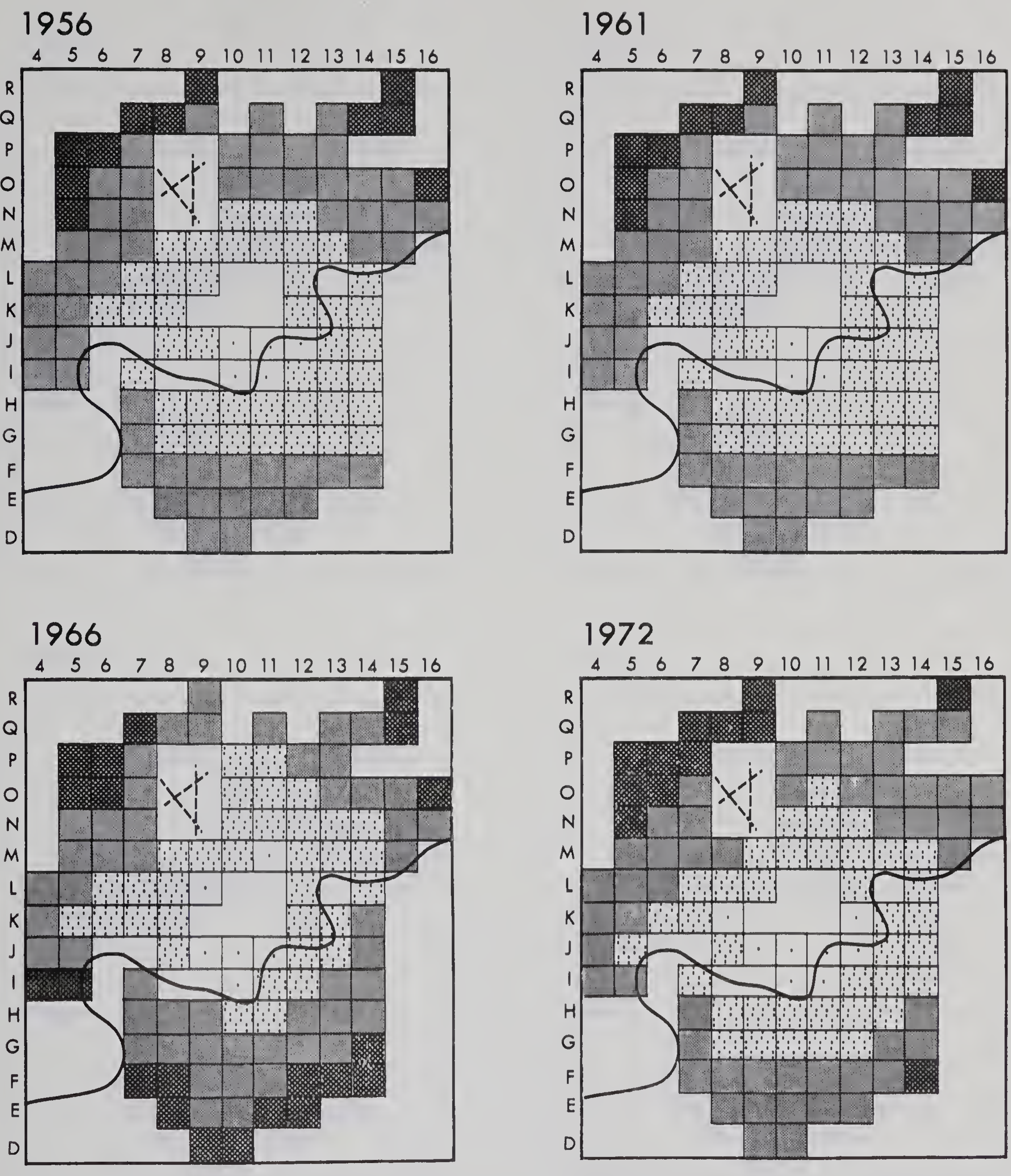


FIGURE 4.5
CAR TRAVEL TIME TO CBD

Source: City of Edmonton Transportation Department

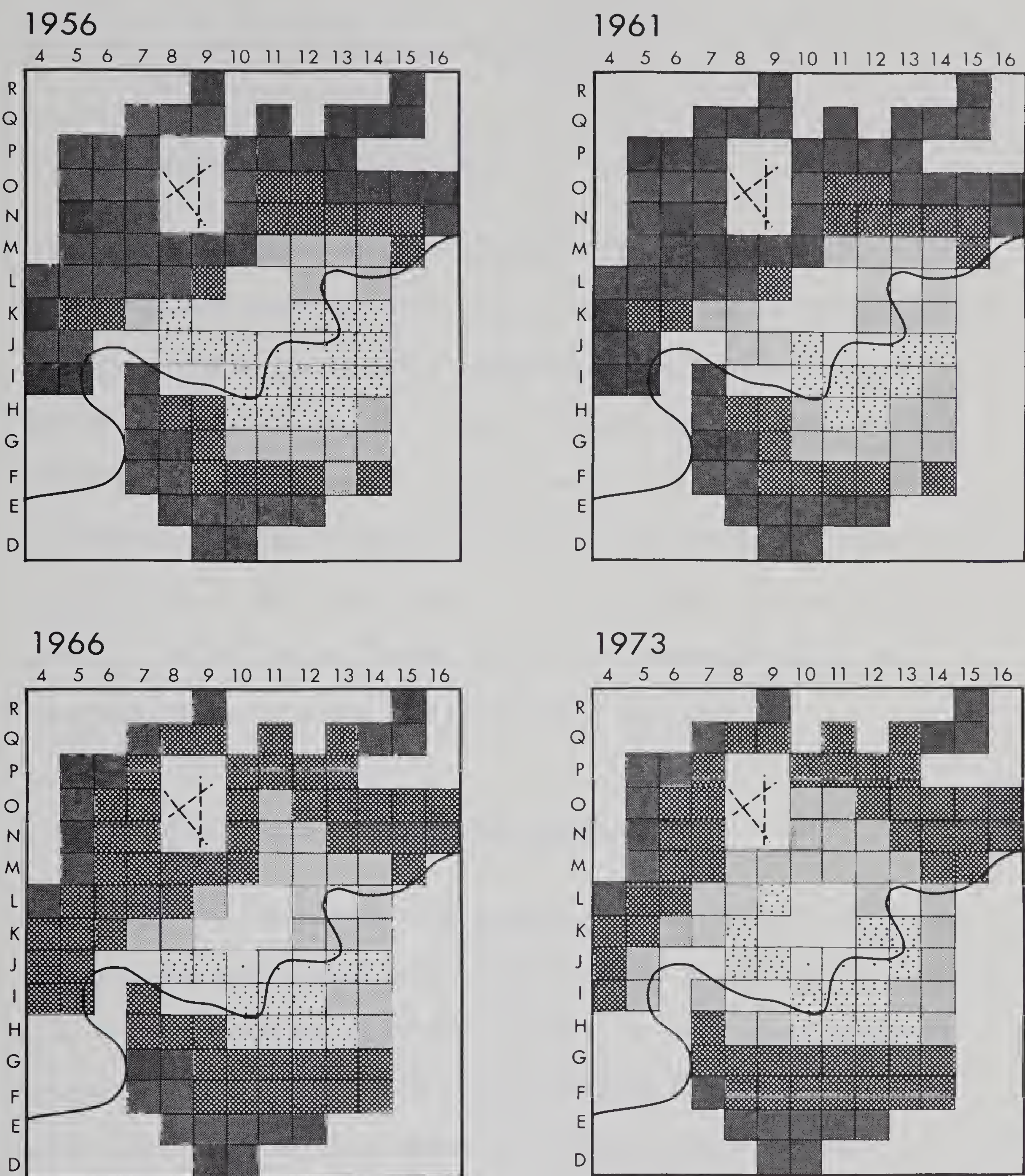


FIGURE 4.6
BUS TRAVEL TIME TO CBD

< 5 minutes
5 to 10 "
10 to 15 "
15 to 20 minutes
> 20 "

Source: City of Edmonton Transportation Department

1956 to the centre of the city in 1973.

4.7 Neighborhood Characteristics

The general procedure of classification and coding the information, that is census tract data and physical values such as air pollution and truck noise, was to first determine the average value of a parameter for a given year, then to compute positive and negative deviations from the mean, to group them and to code the groups. As previously, the most favorable condition with respect to house prices receives the lowest code number. This deviation - from - average method could be applied to the first four parameters only; the remaining three variables defied similar treatment.

4.7.1 Families With Three of More Children

The assumption underlying this parameter is that parents with many children are conditioned to some noise, cries and shouts, and may not object to an addition in form of aircraft noise. Areas with many children are also subject to littering, pranks and even vandalism more than, say, districts inhabited mainly by older people.

The determinant is expressed by the equation:

$$\text{Density} = \frac{\text{families with three or more children}}{\text{total number of families}}$$

Values were available for 1956, 1961, 1966 and 1971, and mean densities for the whole city were 0.216, 0.259, 0.300 and 0.260

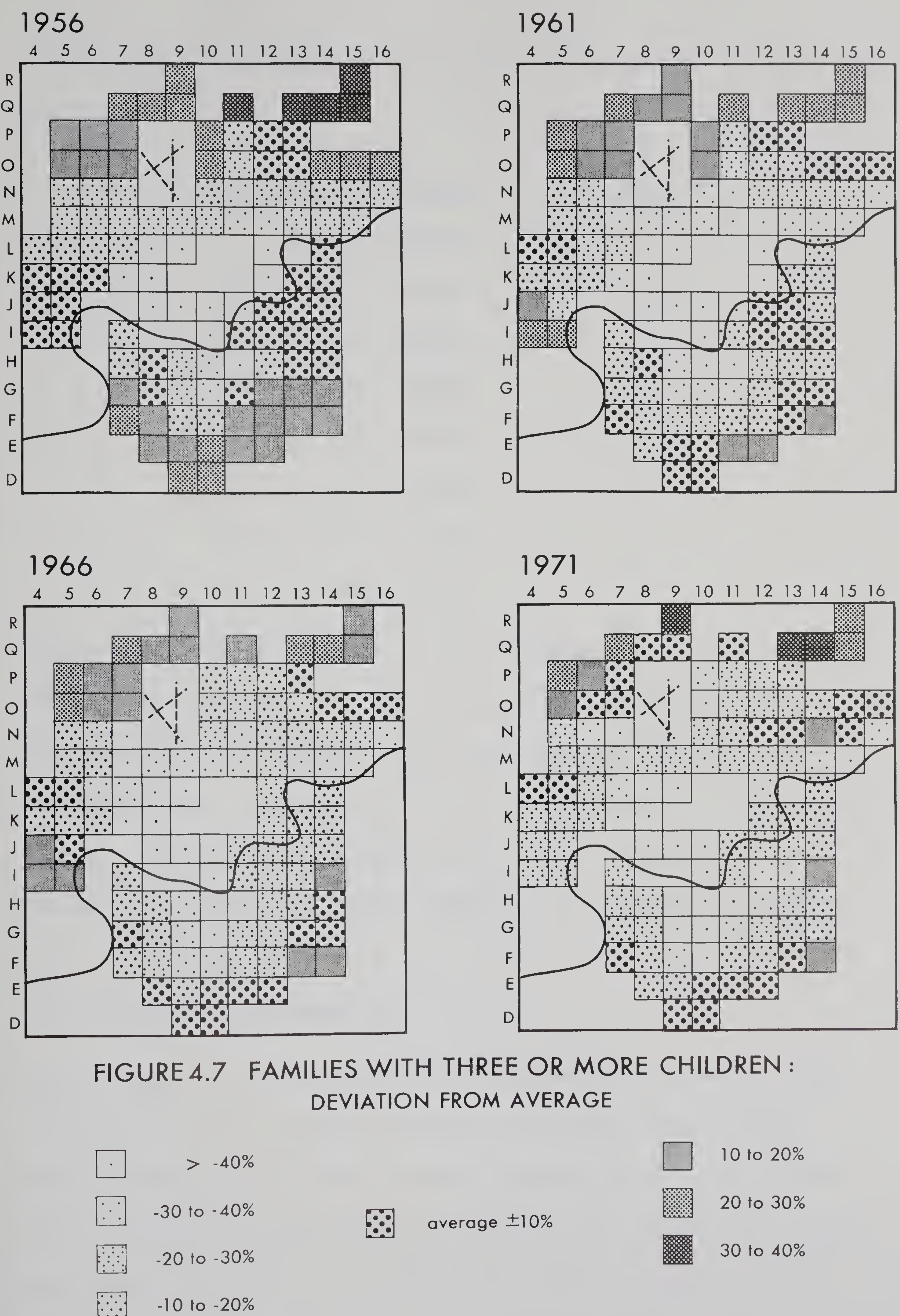


FIGURE 4.7 FAMILIES WITH THREE OR MORE CHILDREN : DEVIATION FROM AVERAGE

Source: Census Canada

respectively. The following code system for deviations - from - average was devised:

deviation from average	code
> -40 percent	1
-30 to -40 percent	2
-20 to -30 percent	3
-10 to -20 percent	4
+10 to -10 percent	5
+10 to +20 percent	6
+20 to +30 percent	7
+30 to +40 percent	8

Figure 4.7 illustrates the historical distribution of families with three or more children. As could be expected, areas with many highrise apartments have not only fewer rooms per dwelling unit, as was demonstrated earlier, but also the lowest number of children per family. The in 1956 outlying districts show a concentration of children, but the trend in 1971 appears to be reduced in strength.

4.7.2 Persons per Household

This variable is closely related to the previous one, and for that reason the coding is equally detailed. The same control years yielded average persons per household rations of 3.7, 3.6, 3.5 and 3.3 with extremes ranging from 4.5 to 1.7. For computation reasons the scales used intervals varying from 5.0 to 5.5 and 6.0 percent.

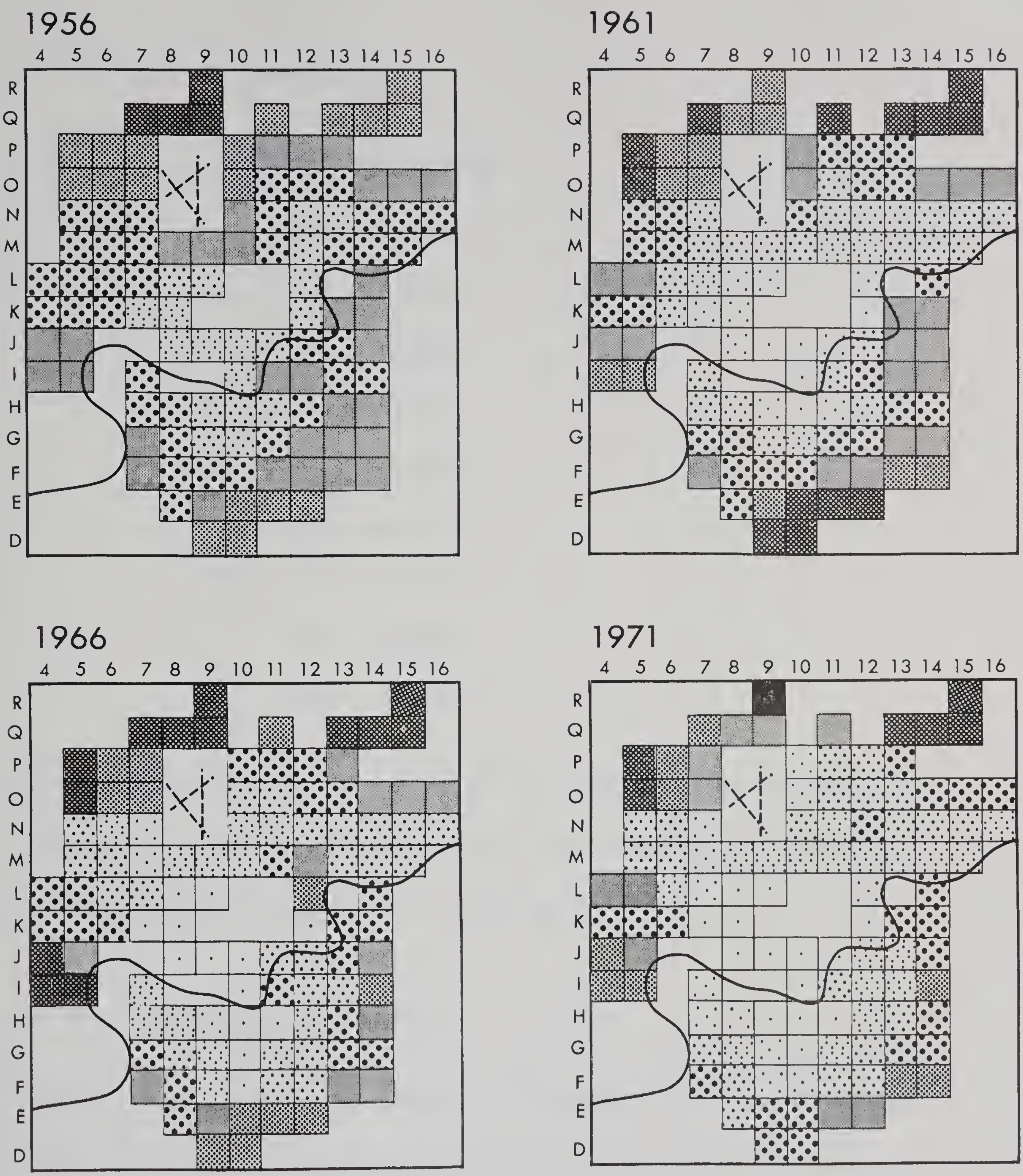
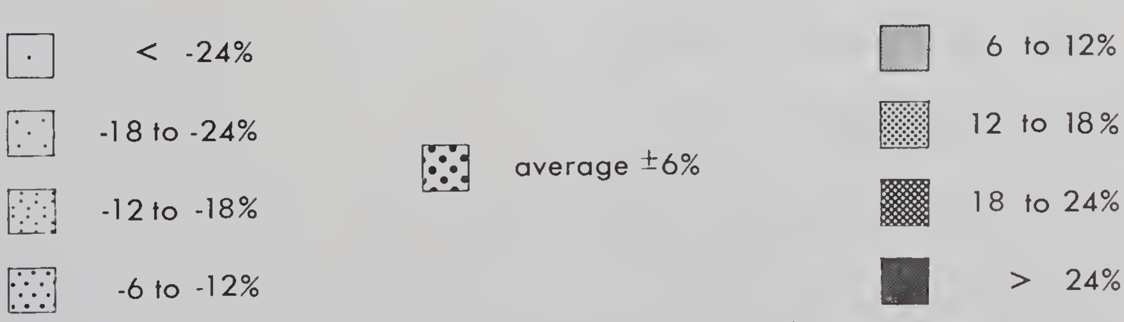


FIGURE 4.8 PERSONS PER HOUSEHOLD:
DEVIATION FROM AVERAGE



Source. Census Canada

Following is an example:

deviation from average		code
> -24	percent	1
-18 to -24	percent	2
-12 to -18	percent	3
- 6 to -12	percent	4
- 6 to + 6	percent	5
+ 6 to +12	percent	6
+12 to +18	percent	7
+18 to +24	percent	8
>+24	percent	9

The change in pattern is graphically illustrated in figure 4.8. Essentially, the low-density areas (below average) are similar to those with high child ratios mentioned before.

4.7.3 Average Family Income

Average family income is generally regarded as an important determinant of property prices, particularly in desirable areas; it therefore deserves close scrutiny. Regrettably, this Census Canada survey is conducted every ten years only (1951, 1961, 1971), so the 1966 value had to be interpolated. Edmonton census data were available for 1951 as well but could not be utilized because of the lack of areal divisions. The 1956 value, therefore, had to be extrapolated.

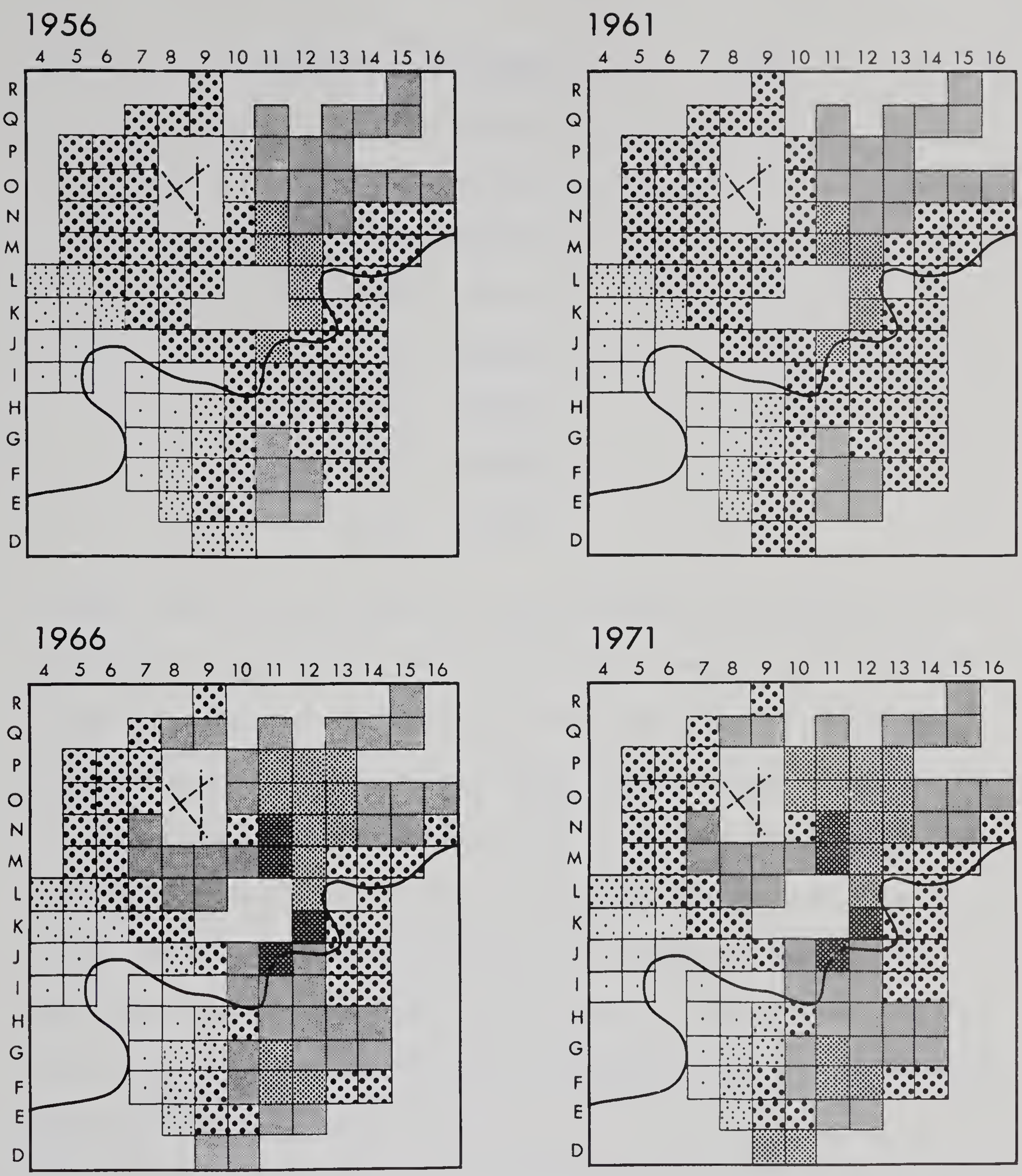


FIGURE 4.9 FAMILY INCOME:
DEVIATION FROM AVERAGE

Source. Census Canada

deviation from average		code
> +40	percent	1
+30 to +40	percent	2
+20 to +30	percent	3
+10 to +20	percent	4
+10 to -10	percent	5
-10 to -20	percent	6
-20 to -30	percent	7
-30 to -40	percent	8

Average values for 1961 and 1971 were $5,400 and $10,660, but an examination of figure 4.9 shows only slight changes in the relative income distribution. It can be said that the range of income was broadened in 1966 and 1971: the number of grid squares representing an average income decreased, while those of lower than average income increased substantially. Also, in 1961 there was no grid with a low of -30 to -40 percent deviation from the mean, while in 1971 there were four, in the Norwood and Riverdale neighborhoods. One can conclude that the gap between rich and poor families has widened over this ten year period.

4.7.4 Crime Rate

As an historic determinant of property prices the crime rate suffers from restricted availability. Only the 1968 and 1973 data could be secured. Prior to 1968 crime information and reports were stored in files, and only since that date has it been stored on computer tapes.

There are usually from thirty to fifty thousand pieces of data to analyze to get total city coverage for one year; thus their sheer number makes a computer programme necessary when city-wide selected information is required.

It was decided to treat the data as if they were taken in 1966 and 1971, but not to extrapolate further.

deviation from average	code
> -70 percent	1
-50 to -70 percent	2
-30 to -50 percent	3
-10 to -30 percent	4
-10 to +10 percent	5
+10 to +30 percent	6
+30 to +50 percent	7
+50 to +70 percent	8
> +70 percent	9

The list of crimes under consideration includes:

police description	computer designation
Murder, manslaughter, rape and wounding with intent	101
Robberies, armed and with violence	102
Purse snatching	102
Assaults	201
Indecent assaults and buggery	201

(P. Engstad, 1974)[3]

[3] University of Alberta, Department of Sociology.

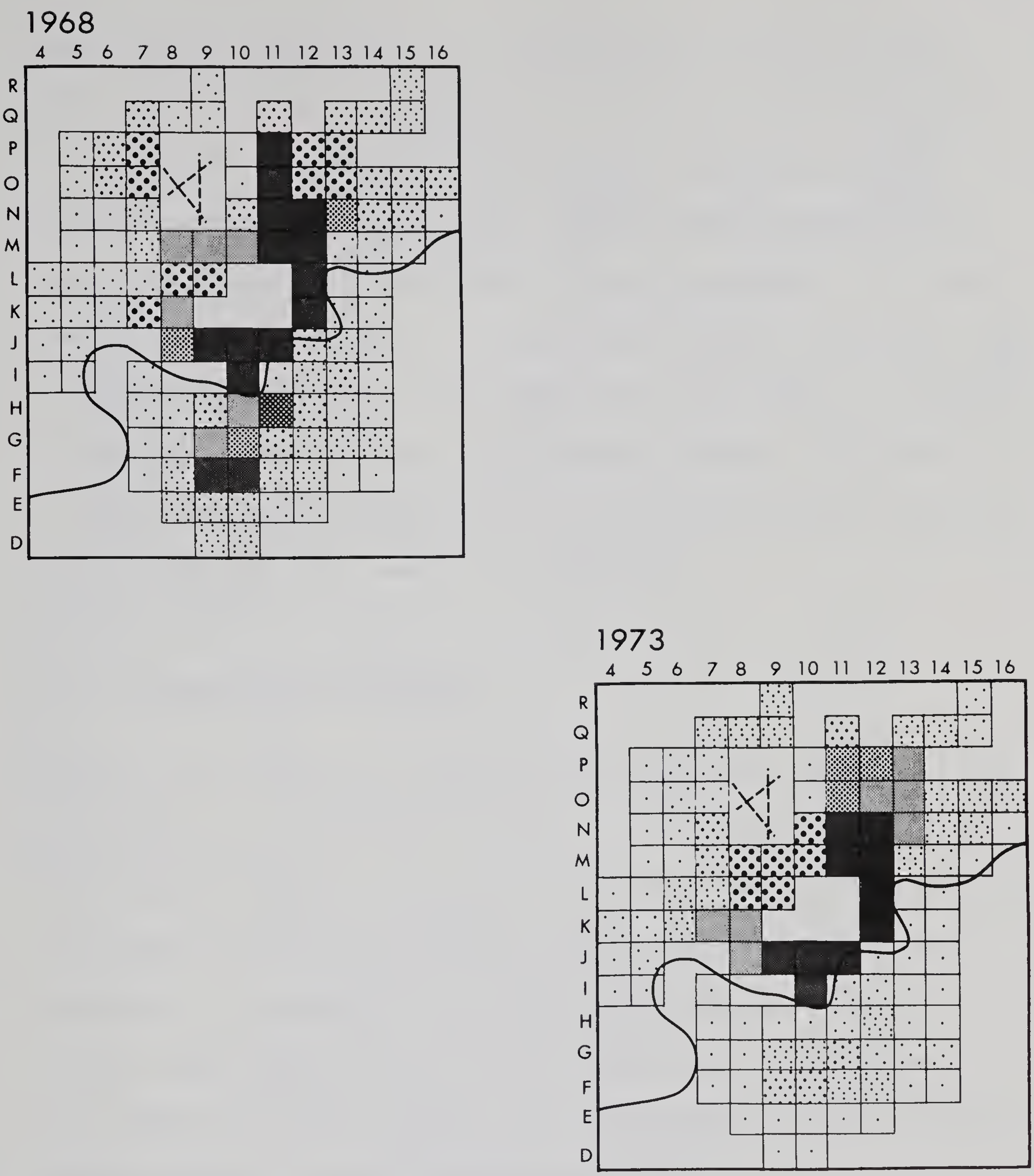


FIGURE 4.10 CRIME RATE:

DEVIATION FROM AVERAGE

- > -70%
- -50 to -70%
- -30 to -50%
- -10 to -30%
- average ± 10%
- 10 to 30%
- 30 to 50%
- 50 to 70%
- > 70%

Source: Stinner, pp.67-69
City of Edmonton Police Department

The crime data thus comprised all personal crimes with violence, those which are liable to make a residential area notorious.

Figure 4.10 depicts the density pattern of those crimes. Not surprisingly, areas with a high crime incidence coincide with those with below - average incomes. The most remarkable development, however, is the emergence of a strong concentration in the inner core of Edmonton in 1973 over a time span of only five years. It is also interesting to observe that in 1973, without exception, the above average crime rate areas lie north of the river. The improvement of South Edmonton in this respect is remarkable.

4.7.5 Freedom from Truck Noise

Ideally, all analyzed properties are free from other intruding sound such as factory, railway and road noise. It was found in a recent noise survey in Edmonton (Bolstad Report, 1973) that factory noises were bothersome only in their immediate neighborhood, but did not rank prominently. The report showed that traffic noise was far more of a nuisance than that of aircraft or railway noise, which rank next. In a sample of 40 areas factory noise was not once cited as the most disliked feature (Bolstad, figures 5a to 5c).

The railway affects only one small section of this thesis' sample, that of grid area P7. The interview conducted with people living in that area showed, however, that aircraft noise was far more bothersome than railway operations. The district lies directly beneath a flight path less than half a mile from runway 11 - 29; furthermore the railway tracks, at that location, are depressed below

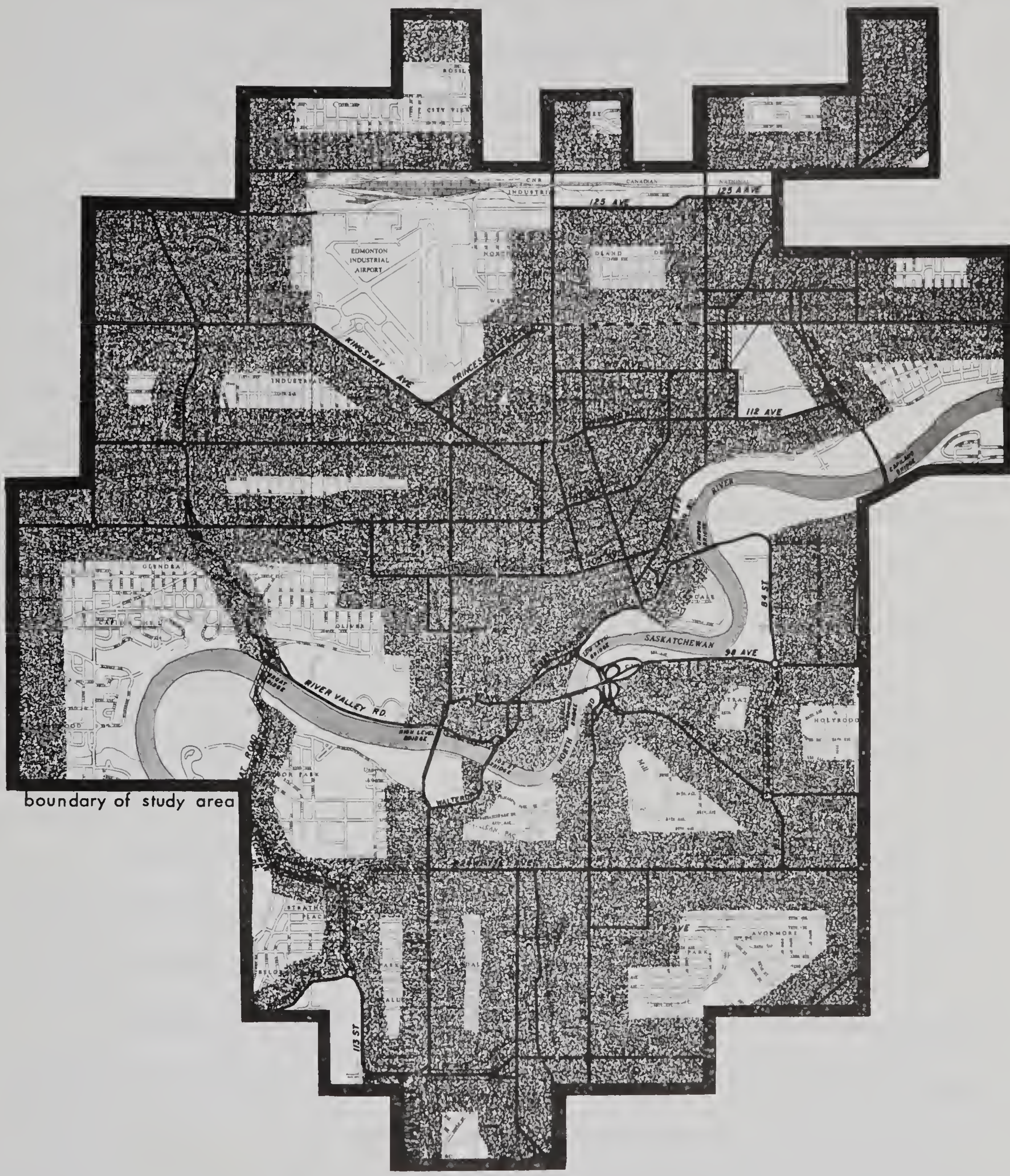


FIGURE 4.11 NOISE ALONG TRUCK ROUTES

residential area covered by truck noise (L 90)

Source: Author's Computation and Arrangement from Data Supplied by Bolstad Engineering

the surrounding land level allowing the slopes to act as noise barriers. Some respondents also commented on the prevailing west wind that carries the sound away from them.

Road noise is, by far, the most common source of noise annoyance. The Bolstad Report found that traffic noises were most bothersome where houses were directly on the artery or truck route, regardless of the location. It was observed that noise decreased rapidly with increased distance from major arteries, a well-known physical law. Generalizing equations that determine sound diminuition with increased distance have been designed for flat, unobstructed areas, but no such formulas are known for residential districts, largely because of the complex interaction of house spacing, house height, building material, landscaping and distance with sound propagation (Bolt et al., 1967; Harris, 1957; and Ostergaard and Donley, 1964).

Realizing that truck noises are more bothersome than the hum of flowing passenger car traffic it was decided to construct a map that shows areas free of truck noise[4].

Bolstad's survey showed that fairly constant quiet conditions were found in the centre of residential cells far removed from major traffic routes. In an effort to generalize those cells for all of Edmonton, this writer selected nine areas arbitrarily but near truck routes and measured the distance from the loudest L90 level to the

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[4]In the selection-of-homes process care was taken to avoid arterial roads other than truck routes as well.

quietest, as shown in Bolstad's Technical Report[5]. Noise from depressed roads or that which intrudes on residential areas of non-linear outlay, such as cul-de-sac formations, was found to travel about one long block or two small blocks before diminishing, while all other residential districts were affected for about twice that distance. These sample measurements were then used to construct a map of truck noise and -noise free areas (figure 4.11).

A comparison with a 1961 truck route map revealed that all of the earlier routes were still truck routes in 1972, but new ones had been added. Since most of the additional routes were major arteries in 1961 as well it is suggested that the map of 1972 be considered as representative for the other control years.

4.7.6 Obnoxious Odor

Figure 4.12 shows the distribution of obnoxious odor. The information was collected in 1972 by Stanley Engineering Ltd., and it is the only one of its kind for Edmonton. The data are based on telephone complaints over a nine month period. Principal offenders were exhaust fumes and chemical sewage and meat processing stenches. The total number of different callers in each coordinate of one square mile (the system used in the Stanley Report) was then classified

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[5] L90 is the noise level that will be exceeded 90 percent of the time, 24 hours long. It is generally accepted as the noise floor, or background noise.

according to this system:

number of callers	code
0 to 2	1
3 to 5	2
6 to 10	3
11 to 20	4
$>$ 20	5

It can be seen from figure 4.12 that there are blocks of 4 grids which have an equal number of complainers. The block formation is a result of the different size grid used by Stanley and this author, 1.0 and .25 square miles respectively.

Local residents are well aware of major odor sources such as meat processing and rendering plants. It is the author's own experience (after having lived for over two years in three different directions from, and close to, a meat packing plant) that neighbors complain about the stench in conversations, and even visitors hear about it. It is argued that word of mouth has reached most people who want to buy a house, thus rendering the affected areas less desirable to live in.

No historic data of obnoxious odor are available and it is intended to eliminate, during the home selection process described later, all grid squares that were subjected to more than 11 complaints in 1972 (see figure 4.12) for none of the areas under a flight path recorded more than 5 complaints. This arbitrary procedure is to eliminate strongly affected areas such as those lying downwind from Gainer's and Burns' meat packing plants.

1972

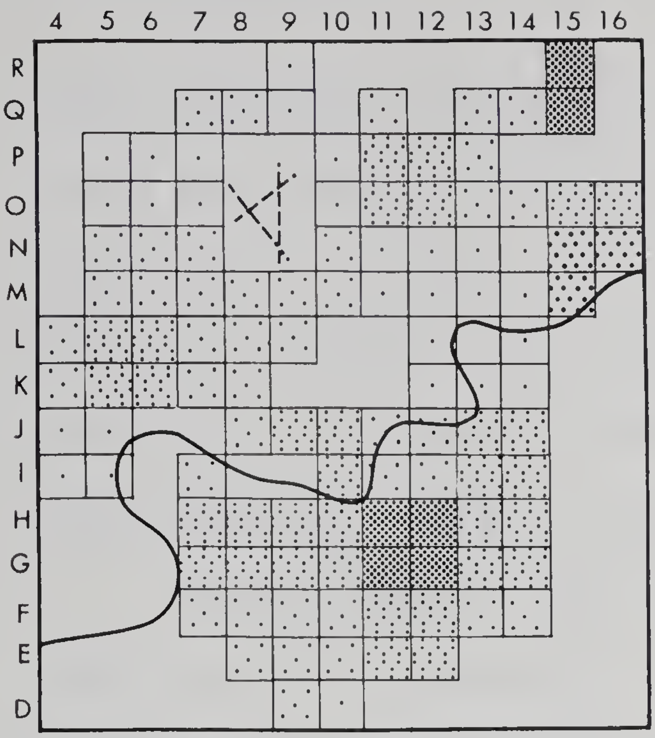

FIGURE 4.12 OBNOXIOUS ODOR

0-2 complainers

3-5 "

6-10 "

11-20 complainers

> 20 "

Source: Stanley Report, 1973

1971

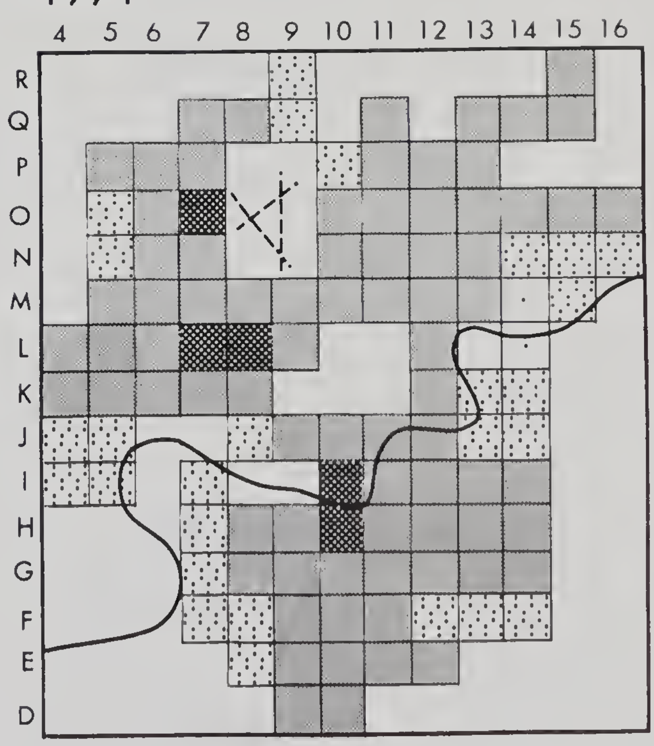

FIGURE 4.13 BOTHERSOME EMISSIONS [PARTICULATES, NO_2 and SO_2]

< 5 sum of codes

5-7 "

8-10 sum of codes

>10 "

Source: Western, 1971

4.7.7 Emission

This is the last parameter to be considered. The only Edmonton survey was conducted in 1971 by Western Research Ltd. Out of the wide range of emissions three were selected whose concentrated presence is obvious and/or bothersome: particulate, NO_x and SO_2 emissions. An informed and alert house buyer could detect an abnormally high pollution level.

The following criteria were applied in the report (Western, 1971) and, for the purposes of the thesis, slightly modified on the hardly detectable end of the emission range:

(1)

particulate emission		sub-code
0 to .5	$\frac{\text{tons}}{\text{year x grid square}}$	1
.5 to 5	"	2
5 to 50	"	3
> 50	"	4

(2)

sulphur dioxide (SO_2)	sub-code
same as above	same as above

(3)

nitrogen oxides (NO_x)		sub-code
0 to 5	$\frac{\text{tons}}{\text{year x grid square}}$	1
5 to 50	"	2
50 to 500	"	3
> 500	"	4

The sub-codes were added up for each grid square and categorized in a final code:

sum of sub-codes	final code
< 5	1
5 to 7	2
8 to 10	3
>10	4

Figure 4.13 reveals the aggregate pattern of those three emissions. Other pollutants such as heat, carbon monoxide (CO) and carbohydrates were disregarded for they cannot be felt or detected immediately and will escape a potential house buyer.

For lack of historical emission data the 1971 distribution, as revealed in figure 4.13, should be regarded as representative for the other years as well. The heaviest pollution within single-family residential areas is found in Rossdale and south of Saskatchewan Drive (I10 and H10 on the grid), in the area between 107 and 111 Avenues and between 114 and 124 Streets. Another pocket of heavy pollution is found in grid square O7, just east of runway 11 - 29 at the Industrial Airport. All five grid squares appear to be of purely residential land use, and the author cannot offer an explanation for the high pollution incidence.

4.8 Discussion and Critique

No ranking of importance was attemted with the help of statistical methods. Intuitively, the author suggests proximity to bus routes, average family income, crime rate and freedom from truck noise and obnoxious odors as the most influential parameters for the house buyer besides not so tangible factors (eg. closeness to friends) that are very difficult to determine. It is suggested that parameters such as average number of rooms and persons per household are less significant. They were included in the survey mainly because their data were readily available.

It might have been desirable to weight the intuitive assessment of the parameters' importance by applying a correspondingly detailed coding and grouping system. An important (judged) determinant such as proximity to bus routes should have been subdivided into eg. 15 distance/walking time units, while for the number of rooms four (instead of the nine listed above) divisions might have sufficed. In a selection of grids a deviation in the bus-route parameter would, therefore, weigh heavier than a discrepancy in the number of rooms. An example will demonstrate the point: a deviation of 50% between crime rates of grid squares A and B could be worth 8 discrepancy points (see also the discussion of 'selection of matching grid squares'), while the same rate of deviation between the probably less important number of rooms could represent just 2 discrepancy points. However, some of the data did not lend themselves to fine subdivision; in particular, the accessibility values were

recorded in 5-minute steps only, up to "$>$20 minutes" (= 5 steps).

The worst shortcomings of the parameters, apart from the rejected ones discussed separately, are found among the crime rates and the map of truck noise-free zones. The enormous variation in crime rate density made classification difficult. In 1968, for example, the average crime rate was .120 crimes per acre with extremes of .002 and 1.372. Similar figures for 1973 were .171 crimes per acre (an increase of 42.5 percent over a five-year period) with .007 and 1.615 as extremes. A few census tracts with exceedingly high rates, however, distorted the average city value. In retrospect it appears that the crime data should have been utilized in a formula that gives a better approximation to reality by correlating the crime density with the population:

$$\text{crime rate} = \frac{\text{number of crimes x population}}{\text{census tract area}}$$

Another approach would be to concentrate on areas zoned R-1 and to use their average crime rate as the basis for further computation.

A comparison of the truck noise-free residential cells (figure 4.11) with NEF contours reveals a dilemma: there is just one small area (in 07) subject to aircraft noise alone. All other annoyance districts experience truck noise as well, thus making isolation of aircraft noise annoyance impossible. To partly overcome this drawback, the comparison houses should be selected at least one short block away from truck routes, and not farther than three, so that all houses are affected by some truck/high-density traffic noise. This precaution ensures a similar L90 noise level in all tests.

To judge the ages of homes and their relative contribution to property prices is difficult, for the value of older homes is subject to strong fluctuations. Factors such as availability of mortgage money, the supply of new homes and (pending) zoning changes have much bearing on their market price and are often more important than age alone. Those determinants, however, operate and interact in intricate manners and thus elude techniques of large-scale quantification. Age was chosen as a very simple proxy of those parameters assuming that, by and large, house prices decline relatively with increased age. The potential process of an absolute price declination is balanced, to some degree, in a growing city, by the general increase in lot value as a result of a slow shift to a more central location as new houses are built even farther from the city centre.

4.9 Selection of Matching Grid Squares

After having determined the socio-economic and locational variables, the next task is to try and match the predetermined flight path grid square with very similar ones, that are aircraft noise-free. It can be seen from table 4.1 that for each noisy grid square there is a comparable square not affected by aircraft noise. The matching process resulted in the following matrix:

Table 4.1 Selection of Matching Grid Squares

flight path grid square	comparable control grid square	similarity (percent)	similarity, except for 'age of homes' (percent)
J9	I10	95.3	95.3
L9	L8	94.8	97.7
M9	M8	100.0	100.0
M10	M8	99.5	99.5
07	07 (noise-free part)	100.0	100.0
07	06	95.3	96.7
P7	06	92.5	93.9
Q9	Q8	92.9	96.7
R9	Q8	86.3	90.1

The similarity index is based on a maximum variation of 212 code numbers; for example, two completely opposing grid squares could be as much as 212 discrepancy numbers apart thus receiving zero percent similarity. Total coincidence results in 100 percent.

Among the selected areas the age of homes was the prime offender causing dissimilarity, therefore the last column of table 4.1 shows the similarity without that variable. In view of its presumably small importance the last column is judged to be more indicative of the grid squares' alikeness.

4.10 Selection of Relevant Houses

At an earlier stage it was suggested that pairs of grid squares will be used to analyze house price trends. Within the pairs listed in table 4.1, residential blocks with houses of reasonably homogeneous appearance were chosen, according to their NEF category. Care was taken to select only those residential blocks (and thus homes) that have been under the same amount of aircraft noise annoyance throughout the study period, eg. under 30 NEF only. Determination of these blocks was facilitated by superimposing the various NEF contours on a large-scale city map; an example can be seen in figure 4.14.

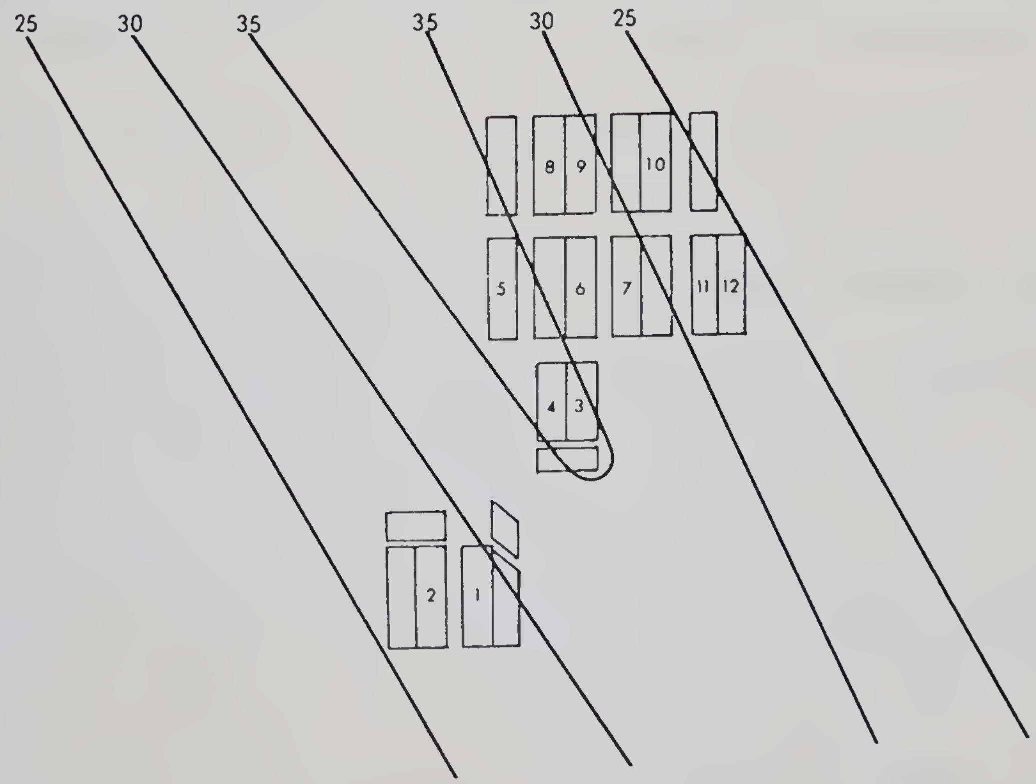

FIGURE 4.14 EXAMPLE OF BLOCK - NEF ARRANGEMENT

It was attempted to include all blocks that were within the 35+ NEF contours. Those within 25 or 30 NEF were too numerous and were selected at random. Blocks within the control areas were chosen randomly as well, provided they were not situated directly on truck, arterial or bus routes. In addition the one-to-three-blocks-from-truck routes rule was adhered to to guarantee a similar background noise.

Within blocks selected through the above described procedure homes were chosen according to outer appearance: those of relatively poor repair or overimprovement were bypassed. To account for a possible nuisance effect corner houses were omitted as well. Where feasible all suitable homes within a block were registered; in very long blocks only homes of a central location were considered. During the field work considerable similarity was found in the appearance of houses in both noisy and control areas; for example, the slightly delapidated homes in grid J9 matched those of the control area (see table 4.1) in I10, and the carefully maintained residences in flight path square M9 were almost identical to those in M8, its control area. Figure 4.15 illustrates the point.

A total of 512 houses was sampled of which 324 were subjected to aircraft noise, as indicated by noise annoyance contours in figures 3.2 to 3.5. One hundred and eighty-eight homes were located in control areas. The greater sample in noisy areas was intended so that a small sample size would not invalidate a possible price - noise intensity ratio, as outlined earlier (see figure 2.3 for an illustration).

R 9

Q 8

M 10

M 8

O 7

O 6

noisy area

quiet area

FIGURE 4.15 SAMPLE OF COMPARISON HOMES

CHAPTER FIVE

SINGLE-FAMILY HOUSE PRICES

5.1 The Question of Value or Price

There have been long arguments about the differences between price and value. Since World War II it has become apparent that there is a well-recognized distinction. Lending institutions have carefully avoided current prices in assessing values upon which they could base safe lending practices. In general, the term value carries a long-range connotation, while a price is short-lived (Hoagland and Stone, 1973). For the past twenty years, real estate prices have advanced rapidly and, while most lending institutions admit that values have risen too, they point out that these have not kept pace with prices. Hence the banks have rejected the idea of adjusting the lending ratio to the prices.[1] They searched for the less tangible evidence of long-range value as an operating basis.

5.1.1 Property Value

There are almost fifty values which may be estimated including, among others, salvage value, market value, insurance value, asking price,

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[1]Banks thought the prices were inflated, often out of proportion to the value. For the home buyer this meant a higher downpayment.

buying price, taxable value, assessment value, fair cash value, most probable selling price and assurance fund value (Frissell, 1966).

The question of property value arises quite frequently within the 'Law of Eminent Domain' which states that private property shall not be taken for public use without just compensation. This term assumes that compensation is just to the owner and to the public. The value of property taken by eminent domain has been declared to be its market value (Sackman, 1973). Yet, market value is only a tool, a means to an end which is the determination of the actual value to be paid in just compensation cases.

Because of the eminent importance of market value a definition is in order:

> The amount of money which a purchaser willing, but not obliged, to buy the property would pay to an owner willing, but not obliged, to sell it, taking into consideration all uses to which the land is adapted and may, in reason, be applied.
>
> (Sackman, p. 68)

It has been argued by Ross (1970) that the procedure for estimating market value is based mainly on historical selling prices of comparable properties. Also the technique of 'recent comparable sales' has been used. Both approaches to market data are riddled with possible fallacies, though: among others , the following assumptions are particularly critical:

- the buyers and sellers recorded in past transactions were dealing in the highest and best use of the property
- the terms of payment were similar
- no party was under pressure to buy or sell

- purchasers and sellers knew all potential uses of the properties
- no depressed-value transactions took place (eg. in the case of sales to relatives or friends)
- sentimental values were approximately equal.

Other property value data that are available to the researcher include the assessment value and, on a more limited scale, mortgage appraisal values. The latter two parameters will be discussed in this section.

5.1.1.1 Tax Assessment Value

In most cases of damage recovery the courts have considered it important that all properties be assessed either at market value or at a uniform fraction of it. Some courts have held that no injury is done to the tax payer if property is assessed at less than its full market value providing the same percentage is applied consistently to all properties within a jurisdiction (Keith, 1966). The same author advises that the assessor must not base his criteria on current sales alone since many are not justified by an analysis of the related economic facts. To do so would be unjust to the property owner (p. 448).

His remarks reveal one of the major disadvantages of using assessment data for an aircraft noise annoyance - property value study: the ratio of sale price to assessment value is not consistent. In fact a pilot study conducted in Edmonton showed that the ratio fluctuated between 23.3 and 48.6 percent (Assessor's Department, 1973).

Thus, the possibility of using assessed values, together with a constant multiplier, as a proxy for sales prices, has to be excluded. Furthermore, since houses are assessed only every five to seven years, a home owner may improve his property considerably and sell it for a much higher price before the city appraiser makes his round again. A low tax on an expensive house could further influence the price.[2] Another possible danger of using assessment data should be carefully examined: do the assessors make provision for homes located under or near the flight path, in that they allow a certain percentage to be deducted from the assessed value? Such an arrangement would render the data useless for the hypothesis of this thesis would be defeated.

5.1.1.2 Mortgage Appraisal Value

Mortgage appraisals are perhaps more realistic in that each home is inspected carefully to determine its actual value. The limitations, however, are similar to the foregoing method: the appraiser might have taken aircraft noise into account; the lending ratio has changed considerably over time (as discussed earlier), even among similar properties in the same year; all homes that were bought without a

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[2] It is argued that this critique is partially reflected in the enormous range of 23.3 to 48.6 percent. According to one source, Mr. J.Thom, supervisor for residential assessment, Edmonton, about one half of all improvements over fifty dollars are unrecorded.

new mortgage have to be excluded; and data collection is difficult because it is hard to identify the various mortgage companies involved.

It is suggested that these restrictions are severe enough to disqualify mortgage appraisal data.

5.1.2 Property Price

The third method of determining changing property 'values' is not by estimation or assessment but by recording sale prices of property. They are probably the easiest data to come by yet they are, as was shown before, subject to fallacies and possible shortcomings. Keith (1966) has warned that sale price data can be the most misleading of all market data analyses. They are full of exigencies for both the seller and the buyer and should not be depended upon unless each sale is thoroughly examined. The most important points to consider are:

- Did buyers and sellers deal in the highest and best use of the property?

  Only single-family homes are under scrutiny, and in a homogeneous neighborhood there is no better use than that indicated by R-1 zoning.

- Did purchasers and sellers know all potential uses of the property?

  In purely residential areas with R-1 zoning the objection loses in importance.

- Were the terms of payment similar?

  Favourable mortgage rates can increase a price substantially; therefore, all mortgage agreements should be recorded in detail.

- Did "depressed price" transactions take place?

  Land title records indicate both the old and the new owner. The researcher should eliminate all sales between parties of the same name. Abnormally low prices will be corrected through a "sworn value" on the transaction document.

- Were sentimental values equal?

  Potentially an important criterion (affection to certain neighbors, childhood memories) it is impossible to quantify accurately.

- Was any party under pressure to buy or sell?

  Unusually high mortgage rates may hint at a pressure to buy, but may also indicate a high-risk property. A very low sale price, on the other hand, could mean a forced sale. These transactions should be excluded.

There are certainly other influential criteria but these six objections are the most important. None of the remedies and precautions suggested is a definite solution to the problem but their application minimize the risk of a biased data sample.

Sales prices have to be collected, and this process in itself is subject to criticism. Only two methods of data collection are feasible, and they will be discussed in the next section.

5.1.2.1 The Multiple Listing Service (MLS)

MLS data are available on a monthly schedule and contain a wealth of information such as vendor's name, size of home, age, number of rooms and, most importantly, listed price, expected down payment, paid price and actual down payment. Another advantage of the system is that transactions between relatives and friends are practically eliminated. Also, Becker (1972) found that MLS data were representative of general housing prices and trends, at least for Oakland, California.

And yet, even if Becker's results and generalizations can be extended to the Canadian market, the Multiple Listing Service does have potentially prohibitive drawbacks, for example:

- none of the transactions that were completed without the involvement of MLS agents would be available. In a small sample a loss of more than sixty percent of the homes, as in the Oakland case, could render the results useless.
- no mortgage conditions are given, therefore pressure to buy cannot be detected.
- perhaps most important is the question of data coding. MLS data are recorded by address within large, numbered tracts of city land. The addresses are not in order; therefore, any attempt to follow up the sales history of a large sample of homes requires the help of a computer. Uncoded data cannot be utilized.

- finally: the establishment of Multiple Listing Services was not uniform in time for all cities and the systematic recording of data might not have begun until a much later date, possibly too late for a meaningful sales history.

If these questions, with the exception of the second one, can be answered positively then MLS data must be considered an excellent source of market price information, while a negative response to only one of them will prohibit the method.

5.1.2.2 <u>The "Transaction Sale" Price</u>

Another system, which is known for its completeness and accuracy, is the "transaction sale" price. The information can be found on transfer of title documents in land titles offices. It represents the real sale price. Advantages of this collection method are that all properties are traceable; mortgages are recorded with date, amount and terms; and misleading sale conditions such as "Agreements for Sale" can sometimes be identified.[3] The method's principal disadvantage is a lack of information on the list price and expected

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[3]Under an Agreement for Sale the vendor sometimes forwards money towards a down payment or a mortgage, but keeps the property's title as "collateral". When the sum is paid off, perhaps ten years after the sale, the title is transferred to the buyer. Thus a title transfer may appear in the documents ten years after the actual sale took place.

down payment, or on any lot and house characteristics.

A peculiar arrangement in the title transfer simplifies the collection of data. The "assurance fund value", in the case of single-family homes, almost invariably coincides with the sale price, thus making a document search unnecessary.[4] The sum can be read off the transfer of title document, together with the other pertinent information.

The Land Titles Act (Chapter 198, 1970) of Alberta defines the assurance fund value as

> The value of land...[which] may be ascertained by the oaths or affirmations of the transferee...and whose oath or affirmation he [the Registrar] is willing to accept.
>
> (s. 161.2)

Usually the sale price appears as the sworn value, which in turn is copied in the assurance fund value. Another provision in the act makes it difficult for artificially low or high sale prices to remain concealed:

> Where for any reasons the valuation of land given to the Registrar is unsatisfactory to him, he may cause an evaluation to be made by an inspector of transfers and such valuations shall be taken to be the value of the land.
>
> (s. 161.4)

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[4]The assurance fund is set up to protect land titles offices against oversights and other mistakes by the recording officers. The assurance fund value, therefore, represents the actual price of the house, if reasonable, or the estimated replacement cost in the unreasonable cases noted.

To sum up: the transaction sale price offers accurate but limited information. Although the collection procedure is cumbersome and time-consuming this avenue to sales data is promising.

5.2 Choice of Pricing System

It was decided to make use of the transaction sale price described above. The reason for its choice was simple: it was the only one feasible for Edmonton. Tax assessment values had to be excluded because homes under a flight path are allowed a tax assessment reduction of up to 8 percent, depending on the noise intensity.[5] These records can, therefore, not be considered for they defeat the hypothesis. In addition, the large fluctuations in the ratio of assessment value to sale price throws doubt on the usefulness of assessment data.

Multiple Listing Service data were available since 1951 but failure to store sales information on computer tapes or cards renders this otherwise valuable source impractical.

The transaction sale prices were determined in two steps:

1. At the Assessor's Department properties were looked up under their addresses, and the legal descriptions were recorded. Since a vendor notifies the taxation

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[5] Personal conversation with Mr. J.Thom, supervisor for residential assessment, City of Edmonton.

office immediately a house is sold, the roll card served as a useful index of transactions. At this stage, out of the original sample, houses with at least two sales over a period of ten or more years, and those with at least three sales over a period of five or more years were selected. All other properties were rejected.

2. The sales histories of the remaining homes (220 out of an original sample of 512) were then traced from files in the Alberta Land Titles Office, where the number of properties dwindled further to 188, due to misplaced files and other adverse conditions. A pilot study comparing 30 assurance fund values with the documented sale prices showed no deviation, therefore all property prices were recorded from assurance fund values. The advantage of this method was a considerable saving in time.[6]

The greatly reduced number of properties made it impossible to execute an analysis price slope vs. noise unit to the desired detail (see

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[6]It should be pointed out that this method is recommended for large-scale price recordings only. A professional appraiser or real estate consultant has to secure the documented sale price as a sound basis for his calculations. An odd discrepancy not affecting the general trend may prove quite important for the individual case study.

figure 2.3). A lack of homes in the 35 and 40 NEF range made the inclusion of those data under a more general 35+ NEF heading advisable.

CHAPTER SIX

ANALYSIS AND EVALUATION

6.1 Comparison of Price Trends

Table 4.1 illustrated the predetermined flight path grids and their control squares, together with an index of similarity. The price trends in those pairs were then compared, and a Student's T-test was administered to determine the significance of variation.

Table 6.1 Significance Test of Variation

pair arrangement		freedom (°)	T value for pair	significantly different at .025?
J9 / I10	(25 NEF)	36	28.98	yes
L9 / L8	(25 NEF)	49	2.353	yes
L9 / L8	(30+ NEF)	48	9.576	yes
M10/ M8	(25 NEF)	44	13.23	yes
M10/ M8	(30+ NEF)	41	24.26	yes
M9 / M8	(25 NEF)	41	4.575	yes
M9 / M8	(30+ NEF)	33	10.70	yes
07 / 07	(25 NEF)	20	130.67	yes
07 / 07	(30+ NEF)	24	7.36	yes
07 / 06	(25 NEF)	33	21.66	yes
07 / 06	(30+ NEF)	33	12.67	yes

P7 / 06	(25 NEF)	33	6.02	yes
P7 / 06	(30+ NEF)	18	5.70	yes
$\genfrac{}{}{0pt}{}{\text{R9}}{\text{Q9}}$ / Q8	(25 NEF)	21	20.66	yes
$\genfrac{}{}{0pt}{}{\text{R9}}{\text{Q9}}$ / Q8	(30+ NEF)	33	13.61	yes
$\genfrac{}{}{0pt}{}{\text{R9}}{\text{Q9}}$ / R9	(25 NEF)	27	1.37	no
$\genfrac{}{}{0pt}{}{\text{R9}}{\text{Q9}}$ / R9	(30+ NEF)	31	28.2	yes

The last column indicates whether sale price trends, that were calculated by feeding sales data (prices and dates) into a computer, are significantly different from each other. The information was needed for each grid square combination as indicated in the first columns. A 'yes' would indicate that, for all purposes (97.5 percent probability) the price trends are different. Of the 17 pairs only one, $\genfrac{}{}{0pt}{}{\text{R9}}{\text{Q9}}$ / R9 (noise-free), 25 NEF, had to be rejected for being too similar in its price trends. The remaining 16 pairs and their slope values (discussed in the next section) had to be accepted; their slopes were so different that there was only a 2.5% chance of randomness.

With this information secured one can now look directly at the price slopes and determine, which and how many of the grid square pairs support the hypothesis, that noise-affected houses increase more slowly in value than noise-free homes. Table 6.2 gives the comparison of slope gradients. One should bear in mind, that the greater the price slope, the steeper is the price increase. Therefore, an area with a lower slope value indicates a more gradual

price increase. This point can be demonstrated with a diagram:

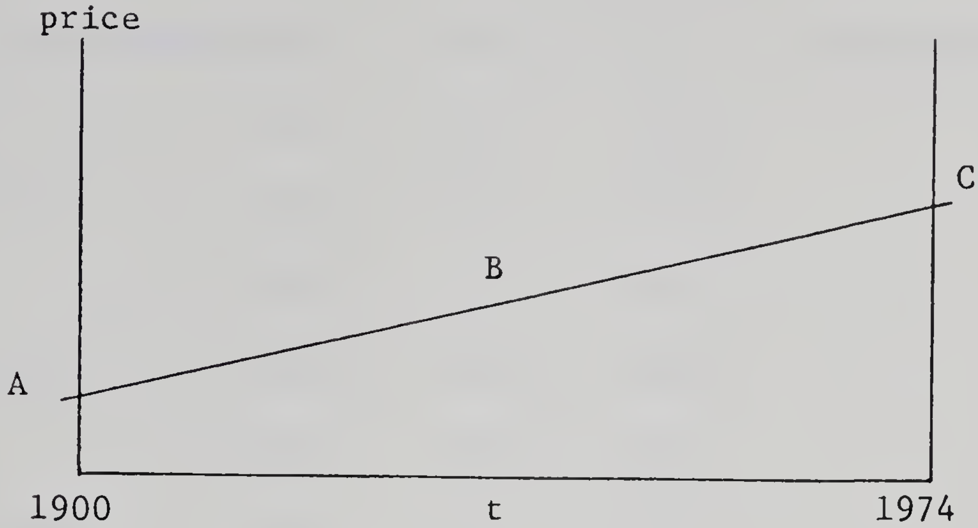

FIGURE 6.1 Example of a Generalized Price Slope

where A = intercept for 0 years (1900)

B = price slope

t = years

C = new value for t years

C is determined as:

$$C = A + Bt$$

If $B = 0$, then $Bt = 0$ $C = A$ for the intercept value would obviously not change. Increasing the slope B results in an increased Bt and C.

Table 6.2 Comparisons of Price Slopes

pair arrangement		price slopes	hypothesis confirmed ?
J9 / I10	(25 NEF)	.02163 / .01508	no
L9 / L8	(25 NEF)	.01543 / .01503	no
	(30+ NEF)	.01752 / .01503	no
M10/ M8	(25 NEF)	.01306 / .01604	yes
	(30+ NEF)	.00978 / .01604	yes
M9 / M8	(25 NEF)	.01722 / .01604	no
	(30+ NEF)	.01266 / .01604	yes
O7 / O7	(25 NEF)	.01541 / .02508	yes
	(30+ NEF)	.02287 / .02508	yes
O7 / O6	(25 NEF)	.01541 / .01866	yes
	(30+ NEF)	.02287 / .01866	no
P7 / O6	(25 NEF)	.02167 / .01866	no
	(30+ NEF)	.02128 / .01866	no
R9 Q9 / Q8	(25 NEF)	correlation only .74672, rejected	
	(30+ NEF)	.05423 / .03857	no
R9 Q9 / R9	(30+ NEF)	.05423 / .01184	no

The result of the above comparison was 9 : 6 against the hypothesis.

6.2 Discussion of the Questionnaires and their Findings

To complement and, hopefully, to reinforce the price-trend data, two questionnaires were administered before the outcome of the price comparisons and significance tests was known. The timing was to

guarantee an unbiased questionnaire design.

6.2.1 The Homeowner Questionnaire

It was felt that a telephone interview would serve the purpose well to fathom people's reaction to aircraft noise, and would put the homeowner more at ease in answering, or refusing to cooperate. The homeowners were selected according to the following method: every house that was owner-occupied and under the influence of aircraft noise was chosen from the final sample of 188. The owners were then contacted by telephone; those who refused to cooperate were naturally labelled as "failures", as were those who could not be reached after five attempts over a three week period. Ninety-two homeowners were approached, and 69 answered and cooperated, thus giving a success ratio of 75 percent.

The following questionnaire was the result of some modifications to a similar one tested in a pilot experiment on seven persons:

1. Why did you purchase this particular house? Was it
    a) close to work?
    b) close to a preferred school?
    c) close to amenities such as arenas, a shopping centre?
    d) the only one you could afford?
    e) for other reasons?
2. At the time of purchase were you aware of the noise path above you?

If yes:

a) could you use your knowledge as a bargaining point?

If no:

b) would you have bought the house for the same price, if you had known?

3. Being in a similar economical and family situation, but knowing what you know now, would you buy in this location again?

4. Have you made any major improvements since you bought the house, such as building a rumpus room, a garage, a patio?

   If no:

   a) did the proximity of the flight path influence your decision?

5. Do you think the noise or flight path makes your home difficult to sell, as the noise makes your district less desirable to live in?

6. Did you get accustomed to the aircraft noise quickly?

7. Are you concerned about a possible aircraft crash?

8. Did the seller tell you about possible noise from aircraft?

9. Did you encounter any difficulties, because of the flight path, in obtaining a mortgage?

10. Do small aircraft bother you more than large ones?

Here are the results:

Question 1 : a = 11 b = 18 c = 3 d = 5 e = 46

Question 2 : yes = 42 (yes-yes = 2
yes-no = 40) no = 26 (no-yes = 16
no-no = 10)

undecided = 1

Question 3 :	yes = 39	no = 27	undecided = 3
Question 4 :	yes = 48	no = 16 (no-yes = 1 no-no = 15)	refused = 5
Question 5 :	yes = 23	no = 31	undecided = 15
Question 6 :	yes = 39	no = 28	undecided = 2
Question 7 :	yes = 37	no = 31	undecided = 1
Question 8 :	yes = 4	no = 49	undecided or non-applicable = 16
Question 9 :	yes = 1	no = 54	paid cash = 14
Question 10:	yes = 29	no = 37	undecided = 3

While the first question served to act as a "filler" and an introduction, it was quickly recognized as a poor initial question, for many people became apprehensive and thought it was too personal. Consequently the interview strategy was changed to asking more neutral questions such as number 6 and number 10 first. The author encountered the most difficulties, however, with question 4: almost all interviewees hesitated with the answer, and five refused it outright. The thought of a tax assessment officer enquiring into taxable home improvements must have been the reason.

With respect to the hypothesis it was felt that questions 2, 3, 5, 9 and 10 were most significant. About 61% of the buyers were aware of the aircraft noise but only two were successful in using it as a bargaining means. Most people agreed, though, that the idea had not even occurred to them. The large segment of buyers who were not aware of the noise is astonishing; yet it is in keeping with the fact that only one out of twelve sellers (agent or home owner) informed the client about possible noise. Is this

evidence that the sellers were reluctant to disclose information that could cause their prospective customers to lose interest? Or is it just that the fact of aircraft noise was taken for granted, in the belief that any prospective buyer would know that the airport was nearby? It is impossible to answer those questions from the homeowner questionnaire alone.

It is of interest to note that ten buyers (39 percent of that segment) would not have bought the house for the same price, if they had known about its exposure to aircraft noise. It is most assuming, however, to expect the owner to distinguish between a fundamental aversion to airplane noise and one that was acquired after living in the house for some time. It should also be pointed out that many owners claim to have been assured by the City of Edmonton that the airport would be closed; about twenty respondents stated that they had bought upon this premise.

Sixty-one percent of the owners who did not know about the noise stated that they would not have changed their purchase decision if they had known. This view is supported by the results of question 3 to some extent, for 59 percent of the interviewees would buy in that particular location again.

Regarding major improvements of the house, only one person out of the 16 who had not improved their houses, cited noise as the reason. At least 70 percent of all homes had been improved,though. This high percentage may indicate that many people intended to stay for a few years at least and thought that to improve on domestic living areas (e.g. building a rumpus room) was a worthwhile

expenditure. This argument is not conclusive, though, for some homeowners may have regarded the home improvement as an investment.

When asked about the ease of selling their houses, the opinion was divided and many interviewees were undecided. The most significant point is that only one-third of the respondents were convinced that resale would be a problem because of aircraft noise. Many of the optimistic views came from the residents in grid square M9, who live in an exceptionally stable neighborhood. Many of them mentioned that they had been approached repeatedly by real estate agents. It was the residents' consensus that a low crime rate (an opinion not confirmed in the crime rate diagrams, figure 4.10), proximity to the city centre, a good bus service and nicely kept homes made for a low turnover rate, and that the desirable features outweighed the noise disadvantage. While grid square M9 was the only noisy area where people were outspoken about positive living conditions, there was no district where negative views were expressed by a majority of the interviewees.

Most people (57 percent) got used to the aircraft noise quite quickly, but those who did not were much more outspoken. When comparing these results with those from question 7, the possible danger from an airplane crash, one can discern a startling fact: the popular assumption that people are annoyed by aircraft noise largely because of an underlying crash fear, was not valid in Edmonton's case. Only 21 respondents gave a "yes-yes" or "no-no" to those two questions (in favor of the assumption) while 48, or 70 percent, answered with a "yes-no" or "no-yes" combination,

thereby refuting a relationship between crash fear and noise annoyance.[1]

The relationship between the availability of mortgage funds and aircraft noise was clear, for only one person had encountered any problems. But the situation may have changed in the last three years, and will do so certainly in the future, as we shall see in the next discussion.

The final point in the homeowner questionnaire was of particular interest: almost one-half (42 percent) of the interviewees complained that small airplanes were more bothersome than the large ones, mainly because of the far greater frequency of operation. This finding emphasizes the need for a new annoyance measure that takes the small aircraft into account.

6.2.2 The Lending Institution Questionnaire

It has been recognized by Central Mortgage and Housing Corporation (C.M.H.C.) officials that noise above 35 NEF is intolerable under any circumstances, save industrial and many recreational land uses, and that homes affected by this level of noise do not merit financing.

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[1]In another case study, in Leduc/Alberta, a strong correlation between trailer home residents' crash fear and noise annoyance from aircraft operating from Edmonton's International Airport was found (author's interview with Mrs. Sarah Trogen, who conducted the study for her M.A. thesis research).

This rule, however, is applied only to new houses; older ones are presently exempted. When the lending institutions were contacted it was with the purpose of getting information about noise-related mortgage policies for new homes. No revelations about finance restrictions on older homes were expected, since question 9 of the homeowner interview had already shown that these were not affected.

Seven banks and seven mortgage/finance companies were approached for answers to the following questions:

1. Does your institution vary its mortgage/construction loan terms or lending policy if a residential development goes up
   a) right under a flight path within 2 miles of the airport?
   b) somewhat away from the flight path, but still in the high-noise zone?
2. Does your institution care whether a flight path with high noise levels crosses a property line, for which a loan application is received?
3. Do you think that a flight path has any impact on the value of residential land or existing residences?

(adopted and modified from Kinnard, 1967)

All of the banks contacted insure their mortgage loans with C.M.H.C. and are thus subjected to that agency's standards and regulations. The loan officers were not prepared to voice the banks' opinions and repeatedly referred to C.M.H.C. loan policies. These can be summarized as:

a) C.M.H.C. does not restrict funds but demands sound proofing in the 30 to 35 NEF range.

b) above 35 NEF no construction or mortgage loans are granted.

c) geographical location in relation to noise sources is unimportant; the noise level received by the individual site is the only factor that is considered.[2]

All of the seven mortgage or finance companies answered. Their responses ranged from a very-much-concerned disposition, where all questions received a definite 'yes', to the could-not-care-less attitude with all questions resulting in a 'no' answer. In fact, all answers fell into these extremes, the ratio being 4 : 3 in favor of the unconcerned attitude. It is interesting to observe, that three out of four mortgage companies were definitely concerned, whereas none of the general finance companies were. This may be a reflection of the willingness of finance companies to accept higher risks than conventional, more conservative lending institutions such as specialized mortgage brokers and chartered banks.[3]

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[2]Telephone interview with Senior Inspector, C.M.H.C., Edmonton Branch.

[3] However, there was no difference in mortgage interest rates between general finance companies and specialized mortgage brokers, but chartered banks were considerably lower in their interest charge.

6.3 The Noise - Penalty Gradient

The earlier suggested model of a noise - penalty gradient (figure 2.4) can be applied to the average results of the $\sum$25, $\sum$30+ NEF and $\sum$control area price slopes. It proved impossible to work out an arithmetic average of logarithmically expressed slopes, therefore a programme was designed that averaged the sales prices for each year within a summation area (e.g. $\sum$25, 30+ NEF). From these a 'summary slope' was computed, but it proved meaningless because of a frequency of sale weighting system that penalizes areas with a low turnover rate. This peculiar problem can be overcome in a large-scale case study, where frequency of sale will approach near-uniformity throughout the entire area and thus becomes insignificant.

Another method was needed, and it was decided to calculate the gains from year to year, thus giving a relative price increase. This task was facilitated and the results became more meaningful because of similar prices in the base year of 1959: controls = \$12,500, 25 NEF = \$13,800, 30+ NEF = \$10,900 and 25,30+ NEF = \$12,600. Using controls as a base (coinciding with the x-axis in figure 6.1) the other price increases were deducted from the base or control value. An example may clarify the method:

> From 1964 to 1965 the base price increase was \$450 for the average house. During this period the 30+ NEF value was only \$300, thus receiving a \$150 penalty. The 25 NEF figure, however, was \$750 and received a \$300 "noise award".

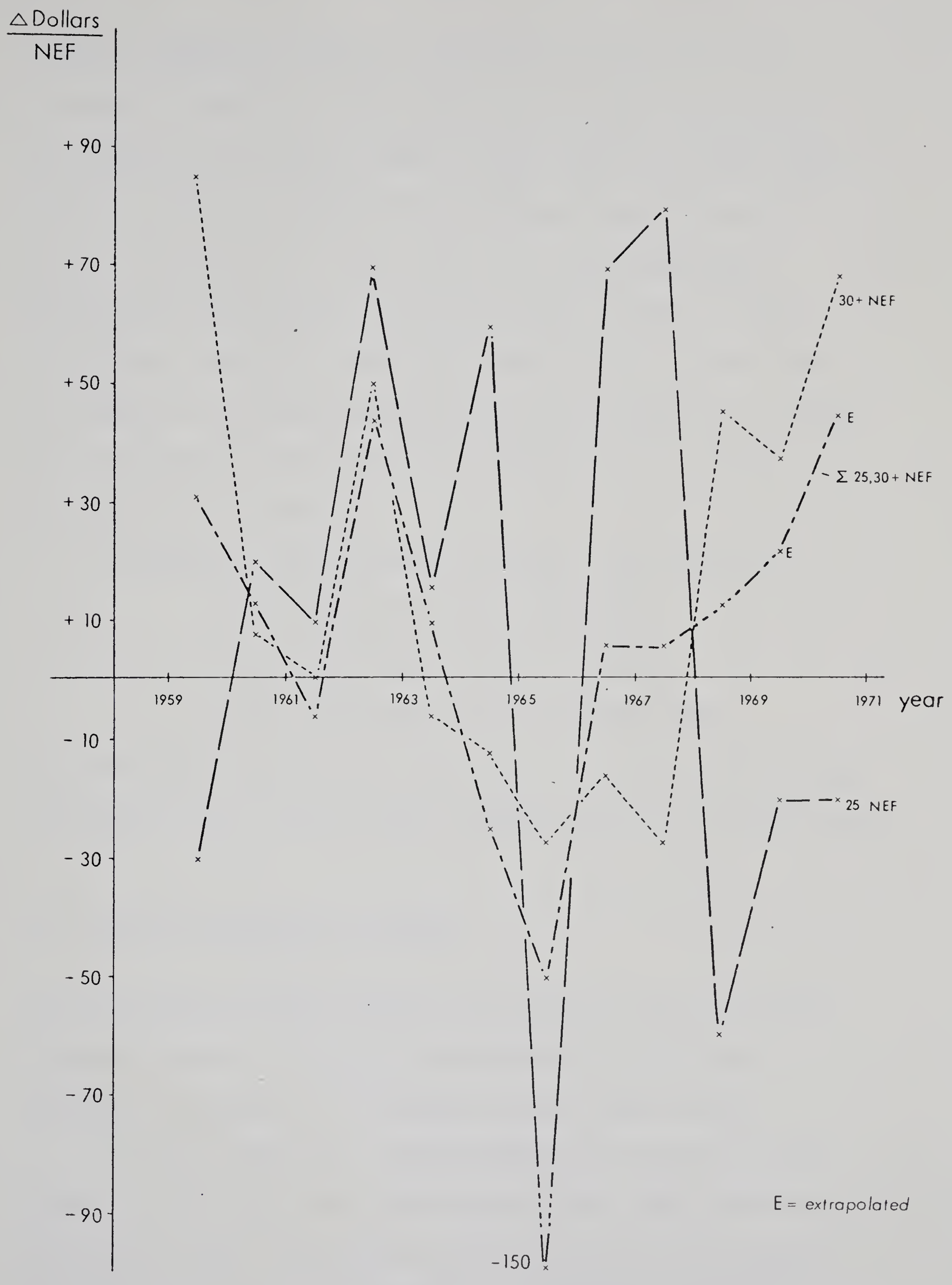

FIGURE 6.2 NOISE PENALTY/AWARD DISTRIBUTION 1959 TO 1971

To gain a $\Delta\$/NEF$ unit number as suggested in figure 2.4 it was necessary to divide the yearly differences in price increases by the NEF deviation from the control. No NEF value for control years could be obtained, but since C.M.H.C. suggests that the first complaints begin at the 25 NEF level, the 20 NEF were chosen arbitrarily as an acceptable background noise (C.M.H.C., 1971). The divisors, therefore, were 5 for 25 NEF, 13 for 30+ NEF (33 NEF was assumed as an average value) and 9 for $\sum 25,30+$ NEF. The adjusted price deviations per NEF were plotted against the years 1959 to 1971, as shown in figure 6.1.

Averaging of the fluctuations showed a "Noise award" of

$3.83 / NEF x year for 25 NEF zones

$17.33/ NEF x year for 30+ NEF zones

$9.08 / NEF x year for $\sum 25,30+$ NEF zones

The wild fluctuations of the 25 NEF curve are deceiving, for it were the noisiest areas, 30+ NEF which recorded the greatest relative gains.

6.4 Critical Evaluation of Results

After analyzing the questionnaires the results of the price slope comparison come as no surprise. But they make the City's tax assessment allowance of 2 to 8 percent appear rather futile.

The price behaviour of grids M10/M8 was not expected. M10's slopes of .01306 and .00978 rank among the three lowest encountered in the whole sample. Since M10 is located very close to a runway, these low values alone would support the hypothesis but gain in

importance when one analyzes the geographical surrounding. Both the Glenrose Children's Hospital and the Royal Alexandra Hospital are within easy walking distance, and the Northern Alberta Institute of Technology is not much farther. Originally it was feared that these major employers would influence the house demand function decisively and thus easily override the noise (supply) component, rendering the findings useless. The opposite result, of course, reinforces the hypothesis.

The two questionnaires and their results blended nicely into the overall picture. There has been no mortgage restriction in the used homes market in noisy districts. If there had been, then house prices would certainly have plunged sharply and might have changed the picture entirely.

It was surprising to see a direct relationship between noise annoyance and price slope: the greater the aircraft noise, the greater the gain. It is very difficult to account for this trend. Obviously, a sizeable segment of the population does not mind airplane noise, no matter how loud it is. Yet it is not understood why the buyer should pay premium prices for the affected homes. The lure of a lower tax assessment, up to 8 percent savings, cannot be strong enough for it hardly exceeds $60 per year. Also, there should be no decisive locational advantage because of the care taken in matching the noisy and the control areas. Not even different kind of zoning categories can be held responsible, for with the exception of J9/I10 all grid pairs were zoned similarly.

It might be suspected that there is a higher turnover rate in the exceptionally loud areas, and that with each transaction the price goes up a little. The fact that many homeowners or agents do not inform their customers about the noise, speaks for this possibility too. But an analysis of the frequency of sale shows very little variation between noisy and quiet areas in general.

In criticism, the relatively small sample size may be the major shortcoming; a few exceptional cases may have influenced the survey unduly. Indeed, one or two exceptional cases per pair could distort the price slope and thus the ratio, for on the average only fourteen houses were analyzed in a grid square, and just seven to eight within an individual noise zone, e.g. L9 (25 NEF).

CHAPTER SEVEN

CONCLUSION

This thesis was based on two hypotheses and two major research objectives. The first hypothesis argued that the intuitive fear of aircraft noise-affected homeowners regarding the relative depreciation of their properties was justified. It appeared that only shortcomings in the legal system, and particularly in the process of collecting evidence, saved aircraft or airport operators from being swamped with damage orders.

Of 16 noisy/quiet grid square pairs that were carefully selected according to a similarity index, six were in favor of the hypothesis, nine against it and one had to be discarded. Thus, for Edmonton's Industrial Airport, it was shown that most of the noisy areas show a faster climb in property prices than their unaffected control counterparts, and that the fear of property price loss was unfounded.

The second hypothesis was linked to two questionnaires that were administered to solidify conclusions reached from price slope analyses. It was argued that homeowners would express their views in accordance with a negative or positive outcome of the first hypothesis. Indeed, a slight majority of the owners contacted in noisy areas did not mind the noise, and most would

buy in the same location again. Interestingly, the ratio was also 9 : 6 in favor of the would-be buyers.

Another questionnaire, that was presented to the loan officers of mortgage and finance companies, revealed no restrictions on noise-affected used homes, and not even Central Mortgage and Housing Corporation (which is usually quite touchy about financing new homes under flight paths) had reservations about investing money in those older homes. Financing restraints would have had serious negative effects on the prices of noise-affected houses. The fact that there were no restrictions supported the favorable price slope behavior of noisy homes; thus the second hypothesis was confirmed.

A major research objective was to develop the retroactive noise annoyance contours through a method that could overcome the lack of exact aircraft movement data from the 1950s and 1960s. The chosen technique was thought to be fairly accurate and annoyance contours for 1955, 1960 and 1966 were constructed. In turn, they permitted the selection, for further analysis, of residential areas that had always been under the same magnitude of noise influence. To ensure this was to improve on the methodology of other authors who had treated noise annoyance contours as fixed.

Of equal importance was the attempt to illustrate graphically a change in physical, locational and socio-economic patterns of the city over the whole study period. The information was then used to compute similarity indices (and "discrepancy numbers")

to locate the best-fitting noisy/quiet grid square pairs which, in turn, served in the price slope comparisons.

The conceptual basis of the thesis was, generally speaking, to develop a more attack-proof method of finding noise-affected areas and to match them with control districts; it is believed that this goal has been achieved. To prove the validity of this argument was, of course, outside the realm of this thesis. Only an actual case, involving damage claims and court action, could substantiate the claim. Also, the method's acceptance by other researchers would be a definite success.

The thesis' findings support the greater part of the literature on aircraft noise, by rejecting the assumption that it necessarily leads to a depreciation of property values. Likewise, it speaks in favor of the majority of court cases, where noise damage claims were rejected rather than accepted. However, the extent to which the outcome of the first hypothesis was influenced by the careful screening of comparison grid squares remains unanswered.

Obviously the screening process was not sensitive enough to some of the influences that make for a price behavior, for a few inconsistencies were revealed. There must have been factors that were even more influential in buying or selling houses, tipping the scale of a supply - demand equilibrium in favor of demand. It might well be that the omitted parameters possessed personal characteristics whose strands are extremely difficult

to unravel, to quantify and to account for in the grid square selection process. Criticism may be offered by reasoning, that man is so complex in his thinking, so unpredictable in his behavior and decision making that no quantitative method, no matter how well devised and applied, can possibly account for all variations. This argument is probably true but, conversely, it can be said that there has to be a system that can, with reasonable accuracy, measure the intuitively most important factors which influence decision-making processes in a family selecting its home. It is hoped that the method developed in this thesis will prove to be fairly accurate and thus acceptable.

There are some shortcomings inherent in the systems involved, and to solve them could well lead into new lines of research. The most severe criticism centers around the difficulty of determining noise annoyance per se. All present methods tend to concentrate on large aircraft of more than 10,000 pounds empty weight. Yet the sheer number of take-offs and landings of aircraft below that weight appears to cancel the noise advantage which they enjoy over larger planes. It was revealed in the homeowner questionnaire and in an earlier study (Bauman , 1971) that small planes tend to be almost as big a nuisance as large ones. However, no EPNdB vs. distance profiles have been constructed for light aircraft as yet; once they are known, they could easily be incorporated into the NEF equation. In view of the large share of aircraft movements, mainly those by light planes of flying schools, omission of that traffic is considered a serious fault

that will lead to inaccurate noise annoyance contours.

The NEF system's stipulation of an "average summer day" made the method of devising retroactive NEF contours possible, but it is argued that an average of at least four values, those of a typical spring, summer, fall and winter day, would provide a better avenue of air traffic generalization, probably the best short of a detailed record (especially when the prevailing meteorological conditions are considered). Of course, under the system used in this study, this would tax the memory capabilities of tower personnel even more, and would increase the likelihood of error.

The selection of those social, locational and other parameters described in chapter 4 was largely influenced by the deemed importance and availability of data. Perhaps only some of them might be secured in a case study in another city, while others might be accessible that had to be foregone in Edmonton. The author sees a need for a basic list of variables that are likely to influence property prices, parameters that can be determined for every city. Additional influences that depend on the nature of the principal variable under scrutiny (e.g. truck noise in an aircraft noise study) can then be added. An accepted reference system of proven or suspected price-influencing variables would make most property value correlations less subject to ambiguities and criticism.

Lastly, it was found that even an initial sample of over fivehundred houses was barely sufficient for a study of this scope,

yet the research involved in tracing down the final 188 house price histories was formidable. In retrospect, it appears that to concentrate on fewer grid squares with more house samples in each would have been preferable. As of now there is a possibility that a few exceptional sales influenced some price slopes unduly.

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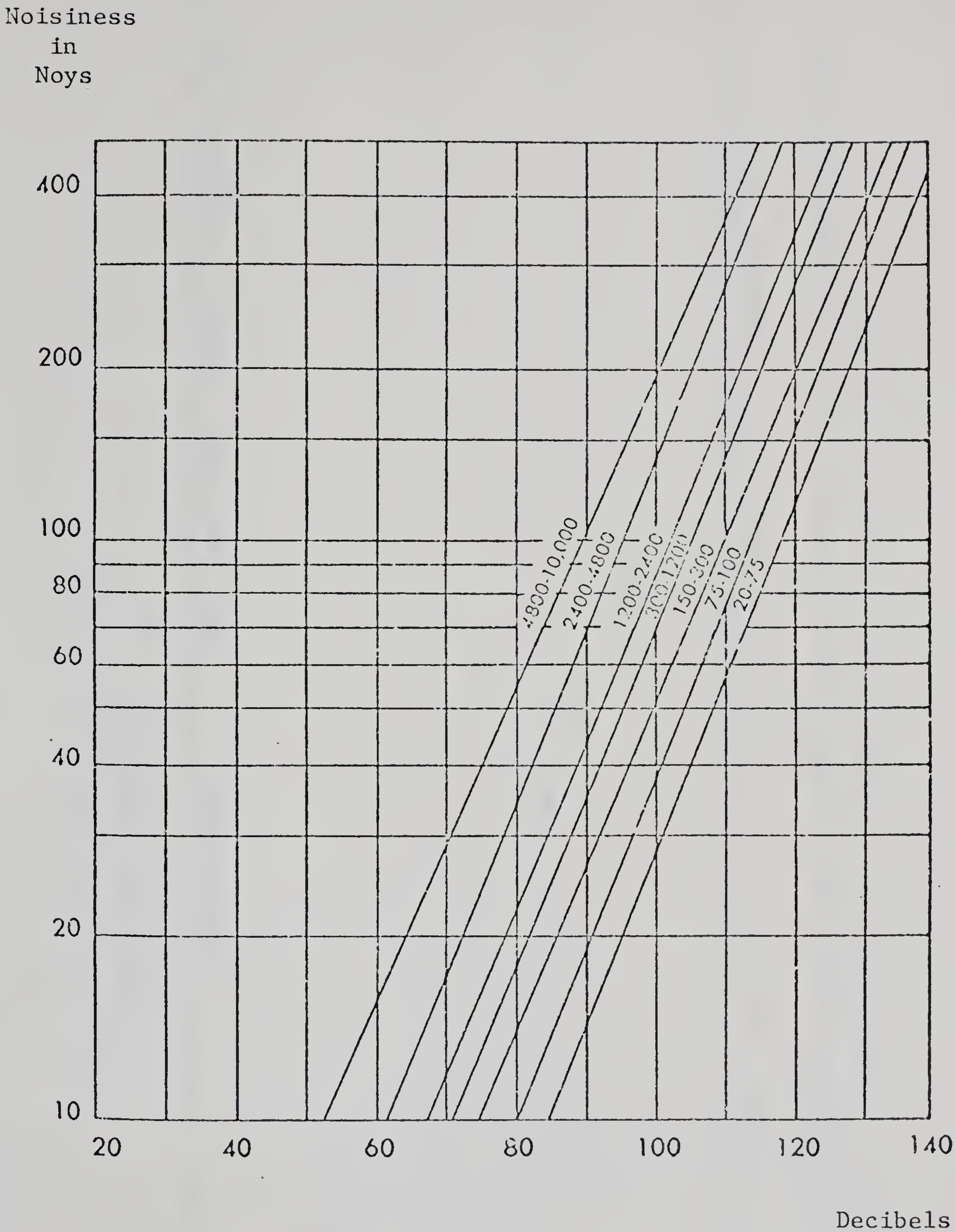
Appendix A

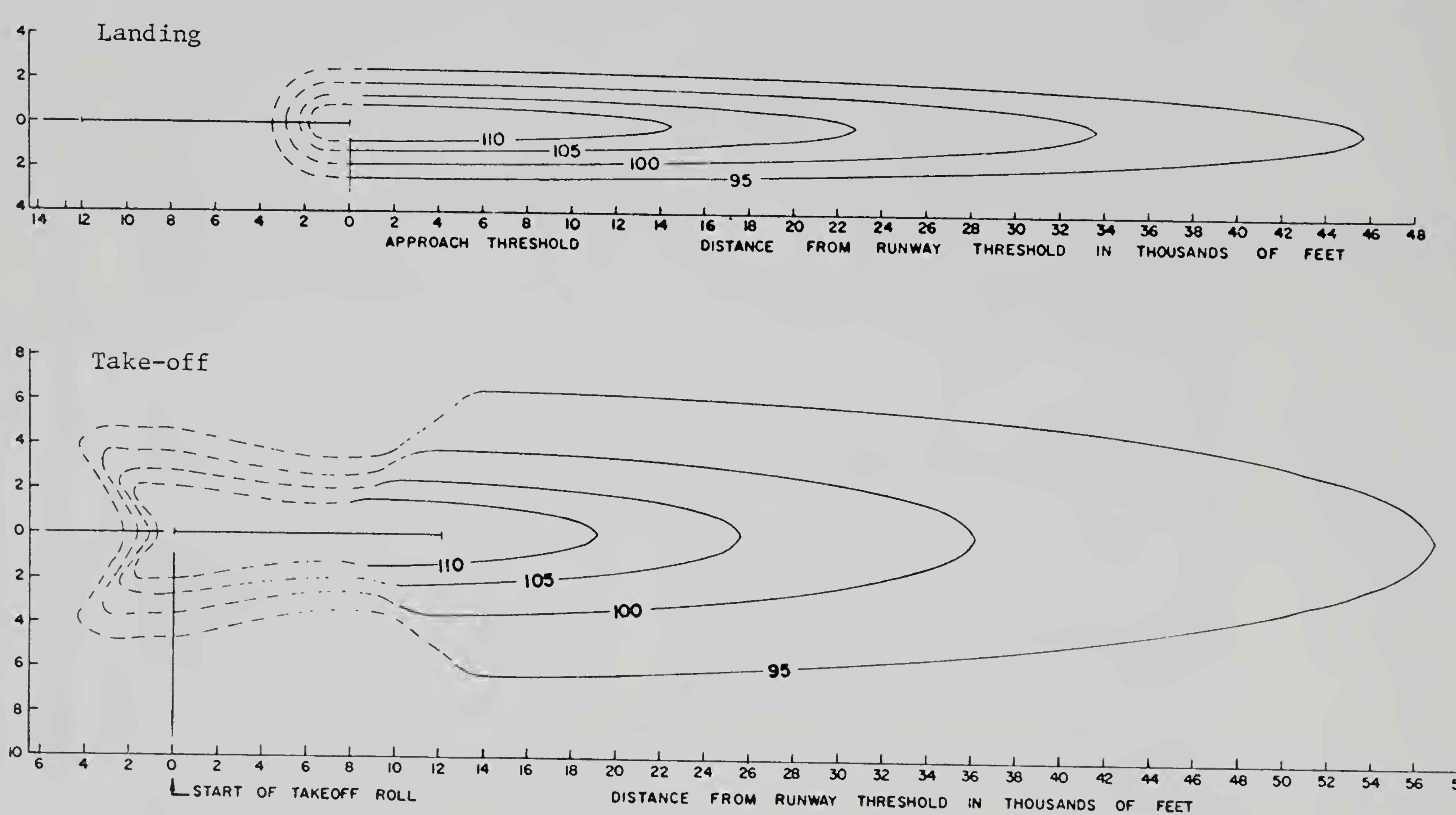


RELATION BETWEEN SOUND PRESSURE LEVEL IN

FREQUENCY BANDS AND NOISINESS IN NOYS.

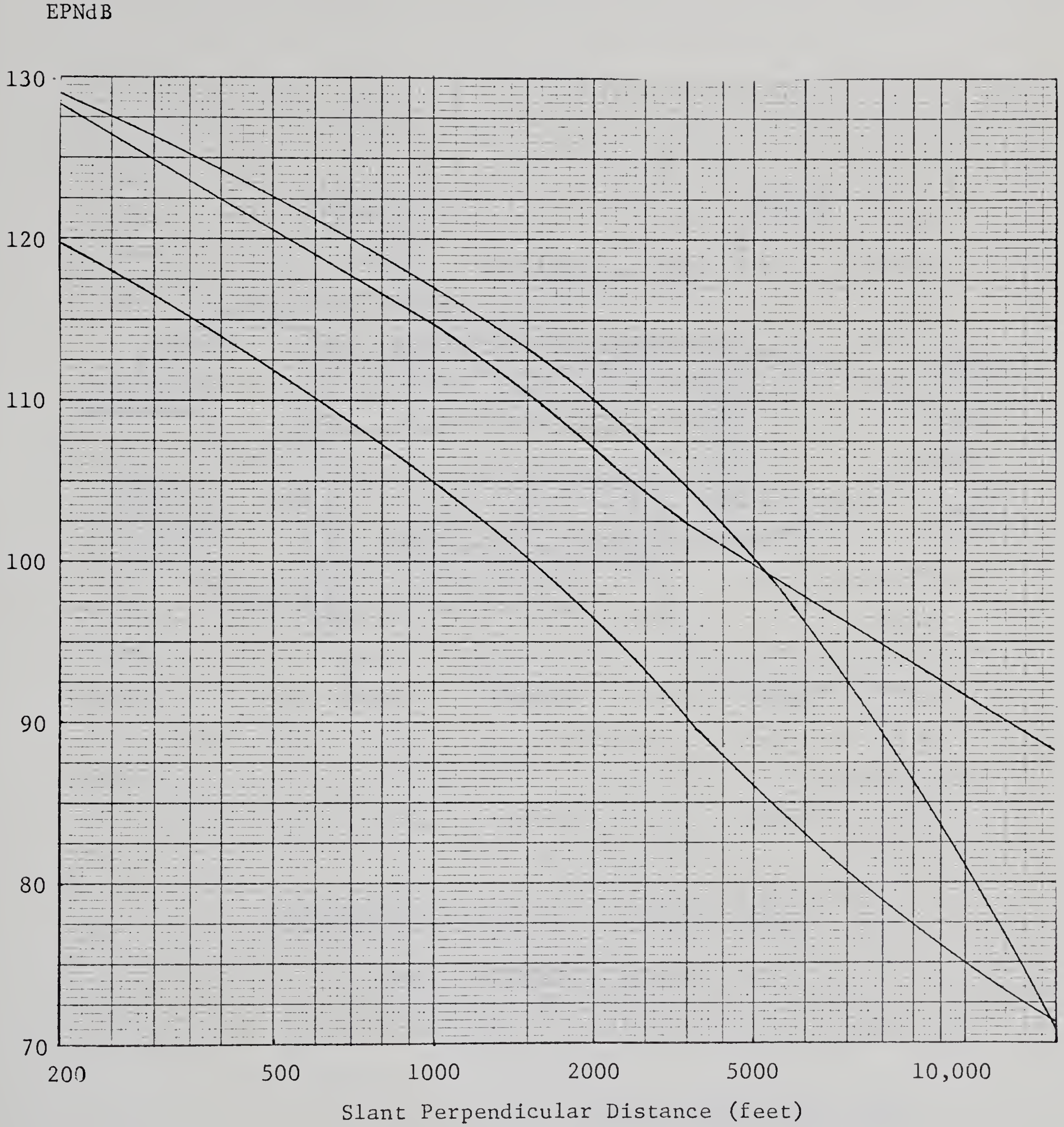
Source: Kryter, 1959, p.1425

Appendix B



EFFECTIVE PERCEIVED NOISE LEVEL CONTOURS FOR TAKE-OFF AND LANDING OF TURBOFAN AIRCRAFT (DC - 8, Boeing 707 etc.) Source: CATA, S - 72 - 8, Appendix B.

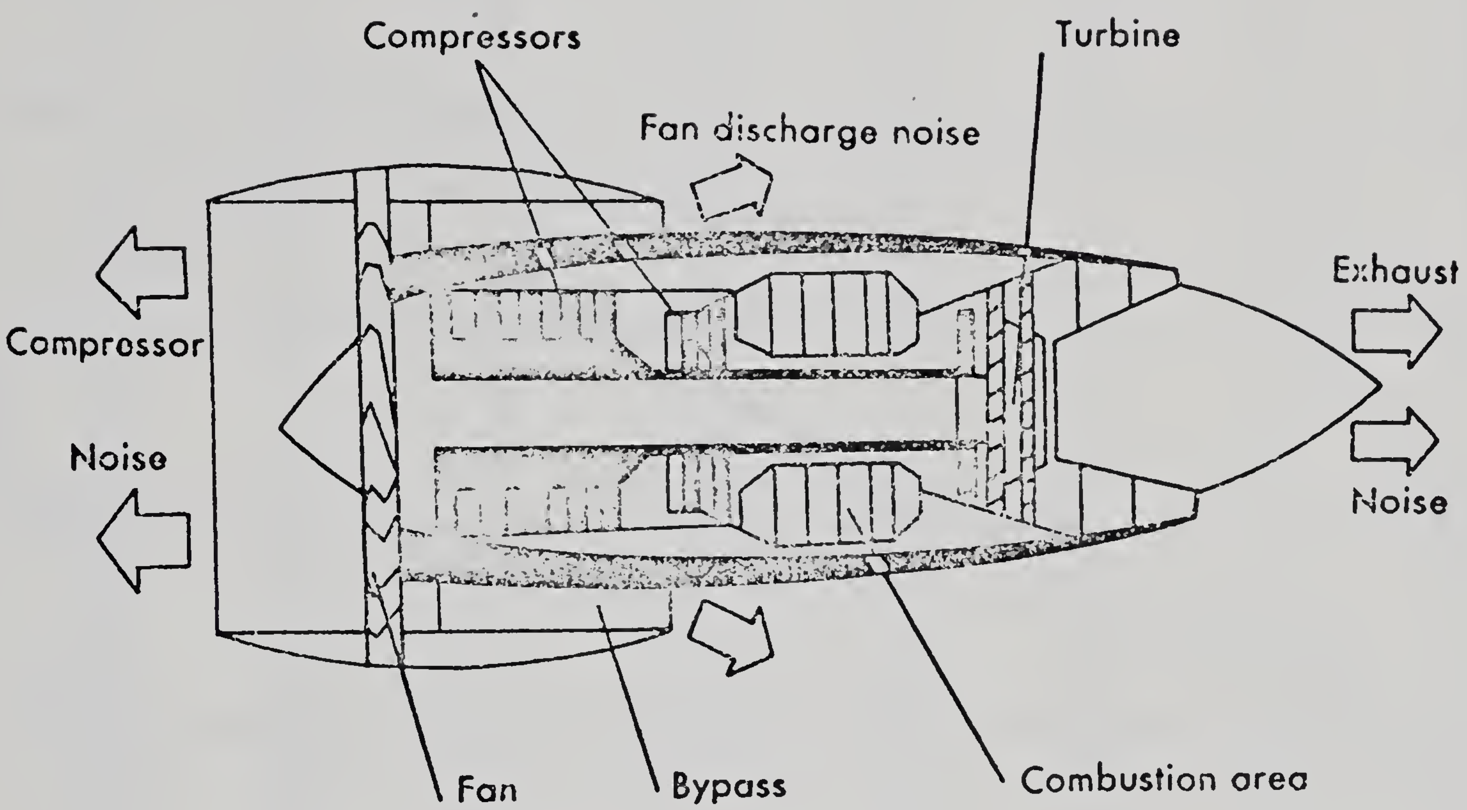
Appendix C



EPNdB VS. SLANT PERPENDICULAR DISTANCE (FOUR-ENGINE TURBOJET)

(Source: CATA, CNR and NEF, p.22)

Appendix D

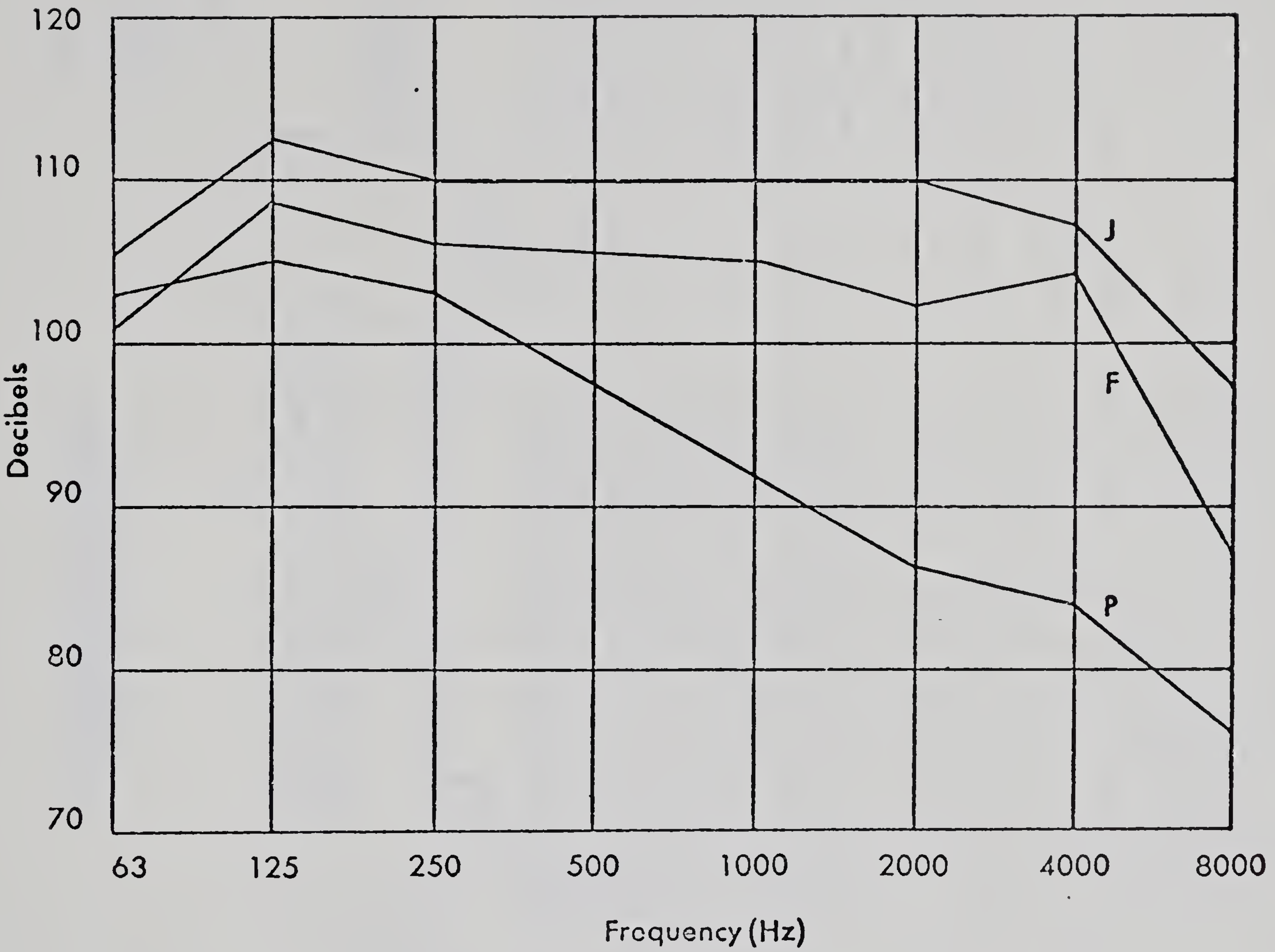


DIAGRAMMATIC SECTION OF A TURBOFAN ENGINE

SHOWING SOURCES OF NOISE

After Bauman, 1971, p.21

Appendix E



FREQUENCY SPEKTRA OF THREE AIRCRAFT TYPES IN FLIGHT: J, TURBOJET; F, TURBOFAN; P, FOUR-ENGINED PROPELLER AIRCRAFT WITH PISTON ENGINES.

After Bauman, 1971, p.19

Appendix F

(Work Sheet)

NOISE EXPOSURE FORECAST
DATA SUMMARY SHEET

DATE June 1974

AIRPORT Edmonton Industrial

FORECAST YEAR 1955

PAGE 1 OF 3

PREPARED BY Hans-Werner Mary

CHECKED BY John Beaton, (Civil Aviation Branch)

AVERAGE SUMMER DAY OPERATIONS (DAY 0700-2200/NIGHT 2200-0700)

AIRCRAFT TYPE	TRIP LENGTH	A/C PROGRAM NO.	OPERATION IDENT. NO.	A/C CODE NO.	RUNWAY (FLIGHTPATH PROGRAM NUMBER) Day/night 29	34	16	11	← → only runways used by large aircraft		TOTALS DAY/NIGHT	24 HOUR TOTALS
DC-3 (2 prop)			8/8	11	3.8 / 0.2	2.28 / 0.12	1.14 / 0.06	0.38 / 0.02			7.6 / 0.4	
DC-4 (4 prop)			6/6	09	2.85 / 0.15	1.71 / 0.09	0.855 / 0.045	0.285 / 0.015			5.7 / 0.3	
DC-6 (4 prop)			2/2	09	0.95 / 0.05	0.57 / 0.03	0.285 / 0.015	0.095 / 0.005			1.9 / 0.1	
C-46			4/4	[illegible]	1.9 / 0.1	1.14 / 0.06	0.57 / 0.03	0.19 / 0.01			3.8 / 0.2	
B-25			6/6	11	2.85 / 0.15	1.71 / 0.09	0.855 / 0.045	0.285 / 0.015			5.7 / 0.3	
C-119 (2 prop)			8/8	11	3.8 / 0.2	2.28 / 0.12	1.14 / 0.06	0.38 / 0.02			7.6 / 0.4	
F-80, 94 (small jet)			5/5	08	2.375 / 0.125	1.425 / 0.075	0.713 / 0.038	0.238 / 0.013			4.75 / 0.25	
Convair 240 (2 prop)			4/4	11	1.9 / 0.1	1.14 / 0.06	0.57 / 0.03	0.19 / 0.01			3.8 / 0.2	
Viscount (4 prop)			4/4	09	1.9 / 0.1	1.14 / 0.06	0.57 / 0.03	0.19 / 0.01			3.8 / 0.2	
Super Constellation (4 prop)			2/2	09	0.95 / 0.05	0.57 / 0.03	0.285 / 0.015	0.095 / 0.005			1.9 / 0.1	
Lancaster (4 prop)			3/3	09	1.425 / 0.075	0.855 / 0.045	0.428 / 0.023	0.143 / 0.008			2.85 / 0.15	
North Star (4 prop)			8/8	09	3.8 / 0.2	2.28 / 0.12	1.14 / 0.06	0.38 / 0.02			7.6 / 0.4	

Appendix G

(Work Sheet)

NOISE EXPOSURE FORECAST
DATA SUMMARY SHEET

DATE June 1974

AIRPORT Edmonton, Industrial

FORECAST YEAR 1960

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PREPARED BY Hans-Werner Mary

CHECKED BY John Beaton (Civil Aviation Branch)

1	2	3	4	5	6	7	8	9	10	11	12	
AIRCRAFT TYPE	TRIP LENGTH	A/C PROGRAM NO.	OPERATION IDENT. NO.	A/C CODE NO.	AVERAGE SUMMER DAY OPERATIONS (DAY 0700-2200/NIGHT 2200-0700) RUNWAY (FLIGHTPATH PROGRAM NUMBER)						TOTALS DAY/NIGHT	24 HOUR TOTALS
					29	34	16	11				
2 prop DC-3			6/6	11	0.285 / 0.15	1.71 / 0.09	0.855 / 0.045	0.285 / 0.015			5.7 / 0.3	
4 prop DC-4			4/4	09	1.9 / 0.1	1.14 / 0.06	0.57 / 0.03	0.19 / 0.01			3.8 / 0.2	
4 prop DC-[illegible]	overseas [illegible]		4/4	09	1.9 / 0.1	1.14 / 0.06	0.57 / 0.03	0.19 / 0.01			3.8 / 0.2	
small jet F-86, T-33			4/4	08	1.9 / 0.1	1.14 / 0.06	0.57 / 0.03	0.19 / 0.01			3.8 / 0.2	
C-46			6/6	09	0.285 / 0.15	1.71 / 0.09	0.855 / 0.045	0.285 / 0.015			5.7 / 0.3	
2 prop C-119			4/4	11	1.9 / 0.1	1.14 / 0.06	0.57 / 0.03	0.19 / 0.01			3.8 / 0.2	
2 prop 240 Convair			4/4	11	1.9 / 0.1	1.14 / 0.06	0.57 / 0.03	0.19 / 0.01			3.8 / 0.2	
Bristol - prop Freighter			2/2	11	0.95 / 0.05	0.57 / 0.03	0.285 / 0.015	0.095 / 0.005			1.9 / 0.1	
4 prop Viscount			8/8	09	3.8 / 0.2	2.28 / 0.12	1.14 / 0.06	0.38 / 0.02			7.6 / 0.4	
Super 4 prop Constellation			4/4	09	1.9 / 0.1	1.14 / 0.06	0.57 / 0.03	0.19 / 0.01			3.8 / 0.2	
4 prop North Star			10/10	09	4.75 / 0.25	2.85 / 0.15	1.425 / 0.075	0.475 / 0.025			9.5 / 0.5	

Appendix H

(Work Sheet)

DATE June 1974

AIRPORT Edmonton Industrial

FORECAST YEAR 1966

NOISE EXPOSURE FORECAST
DATA SUMMARY SHEET

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PREPARED BY Hans-Werner Mary

CHECKED BY John Beaton
(Civil Aviation Branch)

1	2	3	4	5	6	7	8	9	10	11	12	
					AVERAGE SUMMER DAY OPERATIONS (DAY 0700-2200/NIGHT 2200-0700)							
AIRCRAFT TYPE	TRIP LENGTH	A/C PRO-GRAM NO.	OPERA-TION IDENT. NO.	A/C CODE NO.	RUNWAY (FLIGHTPATH PROGRAM NUMBER)						TOTALS DAY/NIGHT	24 HOUR TOTALS
					29	34	16	11				
DC-3 2 prop			2/2	11	0.95 / 0.05	0.57 / 0.03	0.285 / 0.015	0.095 / 0.005			1.9 / 0.1	
DC-4 4 prop			8/8	09	3.8 / 0.2	2.28 / 0.12	1.14 / 0.06	0.38 / 0.02			7.6 / 0.4	
DC-6 4 prop			4/4	09	1.9 / 0.1	1.14 / 0.06	0.57 / 0.03	0.19 / 0.01			3.8 / 0.2	
C-46			6/6	[illegible]	2.85 / 0.15	1.71 / 0.09	0.855 / 0.045	0.285 / 0.015			5.7 / 0.3	
C-119 2 prop			4/4	11	1.9 / 0.1	1.14 / 0.06	0.57 / 0.03	0.19 / 0.01			3.8 / 0.2	
C-130 4 prop	repairs, empty		2/2	09	0.95 / 0.05	0.57 / 0.03	0.285 / 0.015	0.095 / 0.005			1.9 / 0.1	
Convair 240 2 prop			4/4	11	1.9 / 0.1	1.14 / 0.06	0.57 / 0.03	0.19 / 0.01			3.8 / 0.2	
Aircraft private jet [illegible]			1/1	08	0.475 / 0.025	0.285 / 0.015	0.143 / 0.008	0.048 / 0.003			0.95 / 0.05	

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September 1975